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DESCRIPTION

POLYAMIDE RESIN COMPOSITION AND PROCESS FOR PRODUCING THE

SAME

5 Technical Field

The present invention relates to polyamide resin compositions containing polyamide resins and swelling mica treated with particular polyether compounds.

10 Background Art

Polyamide resins have high resistance to heat, chemicals, and weathering and exhibits, for example, excellent mechanical and electrical properties. Polyamide resins are thus used in various industrial applications, 15 such as injection molding materials, fibers, and films.

However, polyamide resins are highly crystalline. When they are formed into a thin product, a complex-shaped product having nonuniform thickness, or the like by injection molding, the product suffers from problems such as 20 warpage resulting in deformation of the product. In order to overcome such problems, in general, incorporation of various inorganic particles has been attempted for improvement. However, this approach also has a problem such as low surface appearance of the product or orientation of 25 fibrous inorganic substances resulting in anisotropy and

thus deformation of the product.

Such problems of inorganic particles are presumably caused by insufficient dispersibility of inorganic particles or excessive size of dispersed particles. A technique for 5 finely dispersing inorganic particles has been desired.

Japanese Unexamined Patent Application Publication Nos. 62-74957, 2-69562, 6-80873, 6-228435, 11-349811, 6-248176, 8-283567, 9-241505, and 2001-2913 disclose polyamide resin compositions containing swelling clay compounds, i.e., 10 inorganic particles, finely dispersed in polyamide resins. In these techniques, swelling clay compounds, such as montmorillonite, are added during the polymerization for polyamide resins. However, clay compounds increase the melt viscosity of the polymer, thereby causing agitation failure 15 during the polymerization. Thus, the amounts of clay compounds that can be used in the polymerization process are as small as approximately several percent, and this has limited the scope of the product design. Moreover, in order to compound auxiliary materials such as a flame retarder and 20 a stabilizer, additional steps are necessary or the process becomes complicated. An improvement as to these points is also desired.

Another problem of the above-described techniques is the use of organic ammonium salts as a surface treatment 25 agent for achieving homogeneous, fine dispersion of swelling

clay compounds. Organic ammonium salts retained at a temperature for processing polyamide resins for a long time undergo deterioration, thereby degrading the properties such as mechanical properties or toughness. This problem must  
5 also be overcome.

Japanese Unexamined Patent Application Publication Nos. 8-319417, 2000-212432, 2000-290500, and 2001-302845 and International Publication No. 97-11998 disclose polyamide resin compositions containing swelling clay compounds finely dispersed in polyamide resins by extrusion. However, in these inventions, dispersion is insufficient, and thus the properties are not sufficiently improved. Moreover, the use of organic ammonium salts as a surface treatment agent for clay compounds may lead to deterioration during the  
10 processing and may degrade the properties such as mechanical properties or toughness. Among the above-described properties or toughness. Among the above-described inventions, the invention set forth in Japanese Unexamined Patent Application Publication No. 2000-212432 requiring end-capped nylon and the invention set forth in  
15 International Publication No. 97-11998 requiring organic ammonium salts having bicyclo rings are not suitable for industrial applications.  
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Japanese Unexamined Patent Application Publication No. 9-118518 discloses a technique for facilitating fine dispersion by rendering layers of swelling clay compounds  
25

readily cleavable. In this technique, a polymeric compound (intercalant polymer), such as polyvinylpyrrolidone, is intercalated between layers of sheet silicate to prepare an intercalation compound. However, although this invention 5 provides the intercalation compound, it does not provide a technique of cleaving the intercalation compound and finely dispersing the cleaved intercalation compound into a polyamide resin. It has been difficult to finely disperse a swelling clay compound into a polyamide resin.

10 Japanese Unexamined Patent Application Publication Nos. 10-259016 and 10-310420 disclose that, in order to cleave a layered swelling clay compound so that it can be finely dispersed in a thermoplastic resin, it is particularly effective to treat the swelling clay compound with a water- 15 soluble compound to convert the compound into an intercalation clay compound. According to this technique, the elastic modulus and heat resistance can be improved without impairing surface appearance. However, further improvements on various properties and on warpage that 20 occurs during injection molding are strongly desired.

As is apparent from the above, there has been no technique of homogeneously and finely dispersing a swelling clay compound in a polyamide resin by a simple process, such as melt-kneading, to obtain a polyamide resin composition 25 having excellent properties.

In order to overcome problems arising from high crystallinity of polyamide resins, e.g., the problem of warpage and deformation that occurs in a thin product or a complex-shaped product with nonuniform thickness produced by 5 injection molding, various approaches other than the use of inorganic particles have been attempted. Examples thereof include alloying of a polyamide resin with a noncrystalline resin, such as a polycarbonate resin, a styrene resin, or a polyphenylene resin. However, this results in degradation 10 of surface appearance or heat resistance of the product, or in deformation of the product due to the anisotropy generated by orientation of fibrous inorganic substances.

An example of alloying a polyamide resin with a styrene resin is disclosed in Japanese Examined Patent Application 15 Publication No. 38-23476 in which a polyamide resin is alloyed with an ABS resin to prepare a polyamide/ABS alloy. Examples of the method for improving the compatibility between a polyamide resin and an ABS resin are disclosed in Japanese Unexamined Patent Application Publication Nos. 63-20 179957 and 64-158, in which a modified copolymer prepared by copolymerization of styrene and acrylonitrile with an unsaturated carboxylic acid is blended. The alloying method using an inorganic filler and a particular type of styrene resin is disclosed in Japanese Unexamined Patent Application 25 Publication Nos. 4-120167, 4-332758, 8-143768, and 9-217006.

The method using a combination of ABS and polyamide prepared by polymerization in the presence of lamellar silicate is disclosed in Japanese Unexamined Patent Application Publication No. 8-3439. The method using a combination of 5 talc, a particular styrenic compound, and a polyamide containing finely dispersed lamellar silicate is disclosed in Japanese Unexamined Patent Application Publication No. 2000-212431. The method using a combination of a thermoplastic elastomer, a styrenic rigid polymer, and a 10 polyamide containing a swelling fluorine mica-type mineral is disclosed in Japanese Unexamined Patent Application Publication No. 9-12873.

However, none of these techniques can simultaneously yield satisfactory surface appearance, deformation 15 properties, heat resistance, and mechanical properties. For example, according to these techniques, the surface appearance (surface quality and low sink-mark formation) is not sufficient, the mechanical properties or thermal properties are degraded by water absorption, or heat 20 resistance is low.

As is described above, polyamide resins are used in various fields. However, polyamide resins have high water absorption and thus tend to exhibit degraded properties once they absorb water. An approach for reducing the water 25 absorption known in the art is to blend polyamide resins

with less water-absorbing resins, such as polyolefin resins (Japanese Unexamined Patent Application Publication Nos. 05-043794 and 06-136259; Fumio IDE, Kazumasa KAMATA, Akira HASEGAWA, "Kobunshi Kagaku [ Macromolecular chemistry ]" The 5 Society of Polymer Science, Japan, February 25, 1968, vol. 25, no. 274, pp. 107-115). However, the polymer blending sometimes results in low heat resistance or lower stiffness. An approach for maintaining the stiffness known in the art is to add fibrous reinforcing materials or inorganic fillers 10 (Japanese Unexamined Patent Application Publication Nos. 06-200087, 06-234896, and 07-108619). However, addition of fiber reinforcing materials results in warpage or deformation of the product due to anisotropy, and addition of inorganic fillers results in low surface quality. An 15 approach for maintaining the surface quality is to add swelling silicate treated with ammonium salts (Japanese Unexamined Patent Application Publication Nos. 10-279752 and 11-181277). However, ammonium salts have low resistance to heat and thus undergo heat deterioration when subjected to 20 heating for a long time at a temperature of processing polyamide resins, thereby resulting in deficiencies such as coloring.

As described above, there has been no technique of producing polyamide resin materials that show satisfactory 25 surface quality, low warpage, high stiffness, and low water

absorption without causing heat deterioration, such as coloring, during the melt processing of polyamide resins.

Recent development in electronic technology has led to an increase in demand for electrostatic recording sheets; 5 housings for electronic devices; electrostatic containers; electrostatic films; floor covering, wall materials, and partitions for clean rooms; covering materials for electronic devices; and magazines for ICs and the like. The materials used therefor must satisfy the required 10 dimensional accuracy, low warpage, surface quality, high stiffness, and heat resistance. Furthermore, since polyamide resins have excellent heat resistance, mechanical properties, and the like, they are used in many industrial applications, such as materials for injection molding, 15 sheets, and films. However, polyamide resins readily become electrostatically charged and thus cannot be directly applied to films, sheets, and containers composed of boards because accumulation of electrostatic charge should be avoided. Accordingly, a technique of rendering electric 20 conductivity to synthetic resins is widely employed. In general, for example, carbon fibers (Japanese Unexamined Patent Application Publication Nos. 7-205310 and 10-237316) and carbon black (Japanese Unexamined Patent Application Publication Nos. 11-310701 and 7-331029) are used.

25       However, when products are fabricated using materials

containing carbon fibers for rendering conductivity, carbon fibers frequently appear in the surfaces of the products. Thus, when such products are used as containers or transfer trays, the surfaced carbon fibers will damage ICs and other 5 electronic components. Furthermore, during molding, carbon fibers align in the direction of flow, thereby generating anisotropy. This leads to another problem, i.e., warpage in the molded products. When carbon black is used, inorganic fillers are used to provide stiffness and heat resistance; 10 however, inorganic fillers decrease surface quality and cause warpage.

As is stated above, a technique that can provide conductive polyamide resin compositions having excellent heat resistance, stiffness, and surface quality while 15 achieving low warpage has not been found so far.

#### Disclosure of Invention

An object of the present invention is to overcome the above-described problems experienced in the conventional art 20 by providing a polyamide resin composition having high dimensional stability, satisfactory mechanical properties, and high heat resistance.

Another object of the present invention is to provide a thermoplastic resin composition having superior surface 25 appearance (surface quality and low sink mark formation); a

thermoplastic resin composition having low water absorption; or a thermoplastic resin composition having an antistatic property.

The present inventors have conducted extensive

5 investigations to achieve these objects and completed the invention by providing a polyamide resin composition with superior properties, in which swelling mica treated with a particular polyether compound is finely and homogeneously dispersed in a polyamide resin by extrusion.

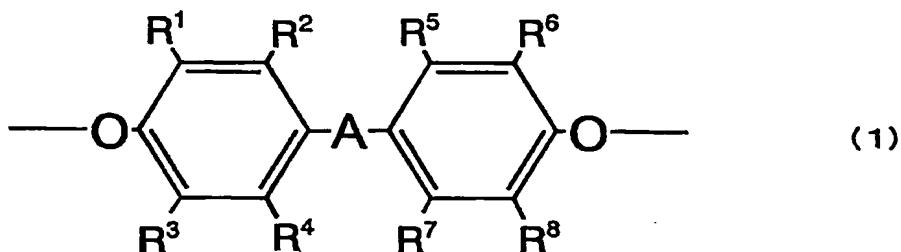
10 The present inventors have also made a thermoplastic resin composition having superior properties, in which swelling mica treated with a particular polyether compound is finely and homogeneously dispersed, by extrusion, in a resin composition composed of a polyamide resin and a  
15 styrene resin.

The present inventors have also found that a polyamide resin composition comprising anhydride-containing olefin copolymer and swelling mica treated with a particular polyether compound can exhibit excellent properties, and  
20 thus completed the present invention.

The present inventors have also completed a polyamide resin composition having excellent properties, the polyamide resin composition containing a carbon compound and being prepared by finely and homogeneously dispersing, by  
25 extrusion, swelling mica treated with a particular polyether

compound.

In particular, the present invention provides a polyamide resin composition comprising a polyamide resin and swelling mica treated with a polyether compound, wherein the 5 polyether compound is represented by general formula (1):



(wherein -A- represents -O-, -S-, -SO-, -SO<sub>2</sub>-, -CO-, an alkylene group having 1 to 20 carbon atoms, or alkylidene group having 6 to 20 carbon atoms; and R<sup>1</sup>, R<sup>2</sup>, R<sup>3</sup>, R<sup>4</sup>, R<sup>5</sup>, R<sup>6</sup>, 10 R<sup>7</sup>, and R<sup>8</sup> may be the same or different and each represent a hydrogen atom, a halogen atom, or a monovalent hydrocarbon group having 1 to 5 carbon atoms).

The present invention provides the polyamide resin composition further comprising at least one of a styrene resin, 15 an anhydride-containing olefin copolymer, and a carbon compound.

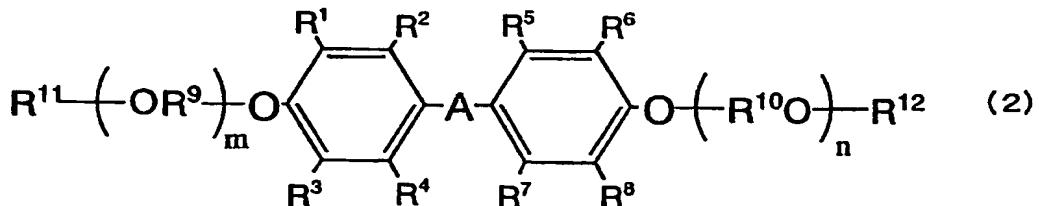
The present invention provides the polyamide resin composition further comprising a styrene resin.

The present invention provides the polyamide resin 20 composition further comprising an anhydride-containing olefin copolymer; the polyamide resin composition in which

the anhydride-containing olefin copolymer is obtained by copolymerization or graft reaction of olefin or an olefin copolymer with an alicyclic dicarboxylic anhydride having a cis double bond in the ring or an  $\alpha,\beta$ -unsaturated 5 dicarboxylic anhydride; the polyamide resin composition in which the content of the anhydride-containing olefin copolymer in the polyamide resin composition is in the range of 1 to 30 percent by weight.

The present invention also provides the polyamide resin 10 composition further comprising a carbon compound; the polyamide resin in which the carbon compound is in the form of particles; and the polyamide resin in which the carbon compound is fibrous.

In a preferred embodiment of the polyamide resin 15 composition, the polyether compound is represented by general formula (2):



(wherein A, R<sup>1</sup>, R<sup>2</sup>, R<sup>3</sup>, R<sup>4</sup>, R<sup>5</sup>, R<sup>6</sup>, R<sup>7</sup>, and R<sup>8</sup> are the same as above; R<sup>9</sup> and R<sup>10</sup> may be the same or different and each 20 represent a divalent hydrocarbon group having 1 to 5 carbon atoms; R<sup>11</sup> and R<sup>12</sup> may be the same or different and each

represent a hydrogen atom or a monovalent hydrocarbon group having 1 to 20 carbon atoms; m and n each represent the number of oxyalkylene repeating units; and  $2 \leq m + n \leq 50$ ).

In a more preferred embodiment of the polyamide resin  
5 composition, the ratio of the swelling mica having an equivalent circular diameter [D] of 300 nm or less in the composition is 20% or more.

In a yet more preferred embodiment of the polyamide resin composition, the average of the equivalent circular  
10 diameter [D] of the swelling mica in the polyamide resin composition is 500 nm or less.

In another preferred embodiment of the polyamide resin composition, the average layer thickness of the swelling mica in the polyamide resin composition is 50 nm or less.

15 In another preferred embodiment of the polyamide resin composition, the maximum layer thickness of the swelling mica in the polyamide resin composition is 200 nm or less.

In another preferred embodiment of the polyamide resin composition, the number [N] of particles of the swelling  
20 mica in the polyamide resin composition is 30 or more per unit weight ratio.

In another preferred embodiment of the polyamide resin composition, the average aspect ratio (layer length/layer thickness) of the swelling mica in the polyamide resin  
25 composition is 10 to 300.

In another preferred embodiment of the polyamide resin composition, the content of the swelling mica in the polyamide resin composition is in the range of 0.5 to 30 percent by weight.

5 In another preferred embodiment of the polyamide resin composition, the polyamide resin composition is prepared by mixing the components described above.

The present invention also provides a method for making  
a polyamide resin composition, comprising melt-mixing the  
10 above-described components of the polyamide resin  
composition.

The present invention also provides a molded resin article entirely or partially composed of the polyamide resin composition described above; and the molded resin  
15 article used in automobile parts.

#### Detailed Disclosure of the Invention

In the present invention, polyamide resins used are polymers that contain amide bonds (-NHCO-) in the main  
20 chains and melt by heating. Examples of such polyamide resins include polycaproamide (nylon 6), polytetramethylene adipamide (nylon 46), polyhexamethylene adipamide (nylon 66), polyhexamethylene sebacamide (nylon 610), polyhexamethylene dodecamide (nylon 612), polyundecamethylene adipamide (nylon  
25 116), polyundecanamide (nylon 11), polydodecaneamide (nylon

12), polytrimethylhexamethylene terephthalamide (nylon TMHT),  
polyhexamethylene isophthalamide (nylon 6I),  
polyhexamethylene terephthal/isophthalamide (nylon 6T/6I),  
polynonamethylene terephthalamide (nylon 9T), polybis(4-  
5 aminocyclohexyl)methane dodecamide (nylon PACM12),  
polybis(3-methyl-4-aminocyclohexyl)methane dodecamide  
(nylondimethyl PACM12), polymetaxylylene adipamide (nylon  
MXD6), polyundecamethylene terephthalamide (nylon 11T),  
polyundecamethylene hexahydroterephthalamide (nylon 11T(H)),  
10 and copolymers and mixtures of these polyamides.

Among these, nylon 6, nylon 46, nylon 66, nylon 11,  
nylon 12, nylon 9T, nylon MXD6, and copolymers and mixtures  
of these polyamides are preferred from the standpoints of  
ready availability, handling ease, and the like. Nylon 6,  
15 nylon 46, nylon 66, and nylon MXD6 are more preferable from  
the standpoints of strength, modulus of elasticity, cost,  
and the like.

The molecular weights of these polyamide resins are not  
particularly limited. In general, polyamide resins having  
20 relative viscosities of 0.5 to 5.0 measured in conc. H<sub>2</sub>SO<sub>4</sub> at  
25°C are preferred.

These polyamide resins may be used alone.  
Alternatively, two or more of these polyamide resins having  
different compositions or components and/or different  
25 relative viscosities may be used.

These polyamide resins may be produced by typical polymerization of polyamides, for example.

In the present invention, polyether-treated swelling mica is used. In this manner, the swelling mica can be 5 finely dispersed in a polyamide resin composition by forming lamellae independent from one another.

The swelling mica used in the present invention may be produced by heating a mixture of talc and a silicofluoride or fluoride of sodium and/or lithium. A specific production 10 method is disclosed in Japanese Unexamined Patent Application Publication No. 2-149415. In this method, talc is subjected to intercalation of a sodium ion and/or a lithium ion to obtain swelling mica. In particular, talc is mixed with a silicofluoride and/or a fluoride, and the 15 resulting mixture is treated at approximately 700°C to 1,200°C to obtain swelling mica. In the present invention, swelling mica produced by this method is particularly preferable from the standpoints of purity and swelling property. In order to obtain swelling mica, sodium or 20 lithium must be the metal contained in the silicofluoride or the fluoride. These may be used alone or in combination.

From the standpoint of yield of swelling mica, the total content or the content of the silicofluoride and/or the fluoride mixed with talc is preferably 10 to 35 percent 25 by weight of the entirety of the mixture.

The swelling silica produced by the above-described method has a structure represented by general formula (3) below:



5 (wherein M represents sodium or lithium;  $\alpha$ ,  $\beta$ ,  $\gamma$ ,  $a$ , and  $b$  each represent a coefficient;  $0.1 \leq \alpha \leq 2$ ;  $2 \leq \beta \leq 3.5$ ;  $3 \leq \gamma \leq 4$ ;  $0 \leq a \leq 1$ ;  $0 \leq b \leq 1$ ; and  $a + b = 1$ ).

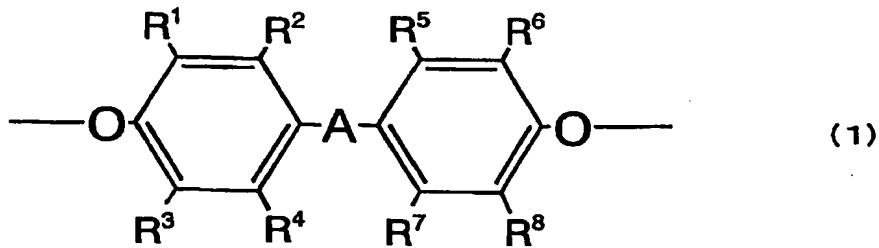
Alternatively, it is possible to add a small amount of alumina ( $Al_2O_3$ ) during the process of producing the swelling  
10 mica used in the present invention so as to control the swelling property of the resulting swelling mica.

This swelling mica swells in water, polar solvents miscible with water at arbitrary ratios, and mixed solvents containing water and any of these polar solvents. In this  
15 invention, "swelling property" refers to the property of mica to absorb polar molecules between the layers, thereby increasing the interlayer distance or to extensively swell, thus leading to cleaving. Examples of the polar solvents miscible with water at arbitrary ratios are the same as the  
20 examples of polar solvents described below.

Examples of the swelling mica include lithium taeniolite, sodium taeniolite, lithium tetrasilicic mica, sodium tetrasilicic mica, substitution products thereof, derivatives thereof, and mixtures thereof. These can be  
25 produced by the method described above.

The swelling mica in an initial aggregation state, i.e., before swelling, has a basal-plane spacing of approximately 1 to 1.7 nm and an average particle diameter of approximately 100 to 100,000 nm.

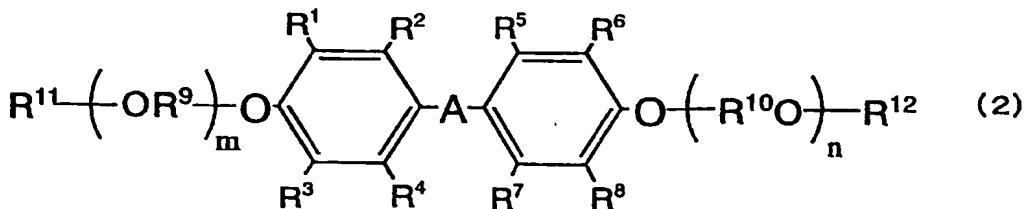
5       The polyether compound used in the present invention includes a structure represented by general formula (1) in the side chain and/or the main chain of a polyoxyalkylene compound such as polyoxyethylene or a polyoxyethylene-polyoxypropylene copolymer:



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(wherein -A- represents -O-, -S-, -SO-, -SO<sub>2</sub>-, -CO-, an alkylene group having 1 to 20 carbon atoms, or an alkylidene group having 6 to 20 carbon atoms; and R<sup>1</sup>, R<sup>2</sup>, R<sup>3</sup>, R<sup>4</sup>, R<sup>5</sup>, R<sup>6</sup>, R<sup>7</sup>, and R<sup>8</sup> may be the same or different and each represent a hydrogen atom, a halogen atom, or a monovalent hydrocarbon group having 1 to 5 carbon atoms).

15       Among the above-described polyether compounds, those having a structure represented by general formula (2) below are preferred from the standpoints of thermal stability, dispersibility of the swelling mica, and ready availability:



(wherein A, R<sup>1</sup>, R<sup>2</sup>, R<sup>3</sup>, R<sup>4</sup>, R<sup>5</sup>, R<sup>6</sup>, R<sup>7</sup>, and R<sup>8</sup> are the same as above; R<sup>9</sup> and R<sup>10</sup> may be the same or different and each represent a divalent hydrocarbon group having 1 to 5 carbon atoms; R<sup>11</sup> and R<sup>12</sup> may be the same or different and each represent a hydrogen atom or a monovalent hydrocarbon group having 1 to 20 carbon atoms; m and n each represent the number of oxyalkylene repeating units; and 2 ≤ m + n ≤ 50).

Examples of the alkylene group having 1 to 20 carbon atoms represented by A above include methylene, ethylene, propylene, phenylmethylene, 1-methyl-1-phenylmethylene, and cyclohexylmethylene. Alkylene groups having 1 to 8 carbon atoms are preferred.

Examples of the alkylidene group having 6 to 20 carbon atoms represented by A include cyclohexylidene, methylcyclohexylidene, dimethylcyclohexylidene, and trimethylcyclohexylidene. Alkylidene groups having 6 to 9 carbon atoms are preferred.

Examples of the halogen atom represented by R<sup>1</sup> to R<sup>8</sup> include a fluorine atom, a chlorine atom, a bromine atom, and an iodine atom.

Examples of the monovalent hydrocarbon group having 1

to 5 carbon atoms represented by R<sup>1</sup> to R<sup>8</sup> include alkyl groups having 1 to 5 carbon atoms. Examples of the alkyl group having 1 to 5 carbon atoms include methyl, ethyl, propyl, butyl, and pentyl.

5 Examples of the divalent hydrocarbon groups having 1 to 5 carbon atoms represented by R<sup>9</sup> and R<sup>10</sup> include alkylene groups having 1 to 5 carbon atoms. Examples of the alkylene groups having 1 to 5 carbon atoms include methylene, ethylene, propylene, butylene, and pentylene.

10 Examples of the monovalent hydrocarbon groups having 1 to 20 carbon atoms represented by R<sup>11</sup> and R<sup>12</sup> include alkyl groups having 1 to 20 carbon atoms. Examples of the groups having 1 to 20 carbon atoms include methyl, ethyl, propyl, butyl, pentyl, hexyl, octyl, decyl, dodecyl, and hexadecyl.

15 In formula (2), m and n each represent the number of oxyalkylene repeating units and satisfy the relationships: m ≥ 1, n ≥ 1, and 2 ≤ m + n ≤ 50.

Examples of the polyether compounds specifically include 2,2-bis(4-hydroxyphenyl)propane ("bisphenol A") 20 containing a polyoxyethylene chain of 1 to 25 repeating units added to each of the termini; 2,2-bis(4-hydroxyphenyl)propane ("bisphenol A") containing a polyoxypropylene chain of 1 to 25 repeating units added to each of the termini; bis(4-hydroxyphenyl)methane containing 25 a polyoxyethylene chain of 1 to 25 repeating units added to

each of the termini; bis(4-hydroxyphenyl)methane containing a polyoxypropylene chain of 1 to 25 repeating units added to each of the termini; 1,1-bis(4-hydroxyphenyl)ethane containing a polyoxyethylene chain of 1 to 25 repeating units added to each of the termini; 1,1-bis(4-hydroxyphenyl)ethane containing a polyoxypropylene chain of 1 to 25 repeating units added to each of the termini; 1,1-bis(4-hydroxyphenyl)-3,3,5-trimethylcyclohexane ("bisphenol TMC") containing a polyoxyethylene chain of 1 to 25 repeating units added to each of the termini; 1,1-bis(4-hydroxyphenyl)-3,3,5-trimethylcyclohexane ("bisphenol TMC") containing a polyoxypropylene chain of 1 to 25 repeating units added to each of the termini; bis(4-hydroxyphenyl)cyclohexylmethane containing a polyoxyethylene chain of 1 to 25 repeating units added to each of the termini; bis(4-hydroxyphenyl)cyclohexylmethane containing a polyoxypropylene chain of 1 to 25 repeating units added to each of the termini; bis(4-hydroxy-3,5-dimethylphenyl)methane containing a polyoxyethylene chain of 1 to 25 repeating units added to each of the termini; bis(4-hydroxy-3,5-dimethylphenyl)methane containing a polyoxypropylene chain of 1 to 25 repeating units added to each of the termini; 2,2-bis(4-hydroxy-3,5-dimethylphenyl)propane containing a polyoxyethylene chain of 1 to 25 repeating units added to each of the termini; 2,2-

bis(4-hydroxy-3,5-dimethylphenyl)propane containing a polyoxypropylene chain of 1 to 25 repeating units added to each of the termini; bis(4-hydroxyphenyl)sulfone containing a polyoxyethylene chain of 1 to 25 repeating units added to 5 each of the termini; bis(4-hydroxyphenyl)sulfone containing a polyoxypropylene chain of 1 to 25 repeating units added to each of the termini; bis(4-hydroxyphenyl)sulfide containing a polyoxyethylene chain of 1 to 25 repeating units added to each of the termini; and bis(4-hydroxyphenyl)sulfide 10 containing a polyoxypropylene of 1 to 25 repeating units added to each of the termini.

Among these, 2,2-bis(4-hydroxyphenyl)propane ("bisphenol A") containing a pentaethyleneoxide chain added to each of the termini, 2,2-bis(4-hydroxyphenyl)propane 15 ("bisphenol A") containing a nonaethyleneoxide chain added to each of the termini, 2,2-bis(4-hydroxyphenyl)propane ("bisphenol A") containing a decapropyleneoxide chain added to each of the termini, 1,1-bis(4-hydroxyphenyl)-3,3,5-trimethylcyclohexane ("bisphenol TMC") containing a 20 nonaethyleneoxide chain added to each of the termini, and bis(4-hydroxyphenyl)methane containing a nonaethyleneoxide chain added to each of the termini are preferred from the standpoints of ready availability and handling ease.

The above-described polyether compounds may contain a 25 substituent or substituents. In particular, the divalent

hydrocarbon groups having 1 to 5 carbon atoms represented by R<sup>9</sup> and R<sup>10</sup> may further contain a substituent or substituents. The substituents are not particularly limited but should not adversely affect the polyamide resins or the swelling mica described above. Examples of the substituents include saturated or unsaturated monovalent or multivalent aliphatic hydrocarbon groups (e.g. alkyl and alkenyl groups); groups containing ester bonds (e.g., alkyl ester groups); an epoxy group; an amino group; a carboxyl group; carbonyl-terminated groups; an amide group; a mercapto group; groups containing sulfonyl bonds; groups containing sulfinyl bonds; a nitro group; a nitroso group; a nitrile group; halogen atoms (fluorine, chlorine, bromine, and iodine atoms); and a hydroxyl group. The polyether compounds may be substituted with one of these or two or more of these.

The content of the substituent in the polyether compound is not particularly limited as long as the polyether compound is soluble in water or a polar solvent containing water. In particular, the solubility of the polyether compound is preferably 1 g or more, more preferably 2 g or more, yet more preferably 5 g or more, still more preferably 10 g or more, and most preferably 20 g or more in 100 g of water at room temperature.

Examples of the polar solvent include alcohols such as methanol, ethanol, and isopropanol; glycols such as ethylene

glycol, propylene glycol, and 1,4-butanediol; ketones such as acetone and methyl ethyl ketone; ethers such as diethyl ether and tetrahydrofuran; amide compounds such as N,N-dimethylformamide and N,N-dimethylacetamide; carbonic acid  
5 diesters such as dimethyl carbonate and diethyl carbonate; pyridine; dimethylsulfoxide; and N-methylpyrrolidone. These polar solvents may be used alone or in combination.

The amount of the polyether compound used can be adjusted to enhance the affinity between the swelling mica  
10 and the polyamide resin and to sufficiently improve the dispersibility of the swelling mica in the polyamide resin composition. If necessary, two or more polyether compounds having different functional groups may be used simultaneously. Thus, the amount of the polyether compound  
15 used cannot be limited by specific numerical values; however, from the standpoint of achieving fine dispersion of the swelling mica, the lower limit of the amount of the polyether compound to 100 parts by weight of the swelling mica is preferably 1 part by weight, more preferably 2 parts  
20 by weight, and most preferably 5 parts by weight. The upper limit of the amount of the polyether compound to 100 parts by weight of the swelling mica is not particularly limited but is preferably 200 parts by weight from the standpoint of achieving fine dispersion of the swelling mica.

25 In the present invention, the process for treating the

swelling mica with the polyether compound is not particularly limited. For example, the method described below may be employed.

First, swelling mica and a dispersion medium are mixed.

5 Here, the dispersion medium is either water or a polar solvent containing water. Examples of the polar solvent containing water are the same as those described above as the examples of the polar solvent.

The method for mixing the swelling mica and the dispersion medium is not particularly limited. For example, 10 the mixing may be performed using a conventional wet mixer. Examples of the wet mixer include high performance mixers having mixing blades rotating at high speeds; wet mills for wet-milling samples in the gaps between rotors and stators 15 at high shear rate; mechanical pulverizers for wet processes using hard media; impact pulverizers for wet processes, in which samples are collided at high speeds using jet nozzles and the like; and ultrasonic pulverizers for wet processes using ultrasonic waves.

20 In order to achieve more efficient mixing, the number of revolutions for mixing may be increased to 1,000 rpm or more, preferably 1,500 rpm or more, and more preferably 2,000 rpm or more. Alternatively, the shear rate may be increased to 500 (1/s) or more, preferably 1,000 (1/s) or 25 more, and more preferably 1,500 (1/s) or more. The upper

limit of the number of revolutions is approximately 25,000 rpm, and the upper limit of the shear rate is approximately 500,000 (1/s). Since mixing or application of shear beyond the upper limits does not improve the mixing efficiency, 5 there is no need to conduct mixing beyond the upper limits. Moreover, the time taken for mixing is preferably 10 minutes or more.

Next, the polyether compound is added, and the mixing is further continued to thoroughly mix the components.

10 The mixing may be performed with a conventional mixer. Mixers are classified into batch mixers and continuous mixers. Examples of the batch mixers include open-type rollers, closed-type banbury mixers, and kneader-type mixers. Examples of the continuous mixers include single-shaft rotor 15 mixers, twin-shaft rotor mixers, single-shaft screw mixers, twin-shaft screw mixers, and multishaft screw mixers. After the mixing, drying and, if necessary, powdering may be performed.

The lower limit of the ash content in the polyamide 20 resin composition derived from the swelling mica is preferably adjusted to 0.5 percent by weight and more preferably 1.0 percent by weight to improve mechanical properties and reduce warpage. The upper limit of the ash content is preferably adjusted to 30 percent by weight, more 25 preferably 25 percent by weight, yet more preferably 20

percent by weight, and most preferably 15 percent by weight from the standpoint of surface appearance of the resulting product. The ash content may be determined according to Japanese Industrial Standards K 7052.

5       The ash content in the polyamide resin composition derived from the swelling mica corresponds to the weight ratio of the swelling mica to the polyamide resin composition (the weight of the polyether compound used in treating the swelling mica is not included).

10      The structure of the swelling mica dispersed in the polyamide resin composition of the present invention is completely different from the structure of the swelling mica before use. Whereas the swelling mica before the use has micrometer-order aggregated structures consisting of many  
15 thin layers, the swelling mica after treatment with the polyether forms independent fine segments as a result of cleaving of the layers. Consequently, the swelling mica becomes dispersed in the polyamide resin composition by forming significantly fine lamellae independent from one  
20 another. The number thereof is markedly larger than the number of the swelling mica particles before the use. Such a state of dispersion of the lamellar swelling mica can be expressed by the equivalent circular diameter [ D ], the number of dispersed particles, the maximum layer thickness,  
25 the average layer thickness, and the aspect ratio (layer

length/layer thickness).

The equivalent circular diameter [ D] is defined as the diameter of a circle having the equivalent area as the particle of the swelling mica dispersed in various shapes  
5 observed in a micrograph or the like. Of the swelling mica particles dispersed in the polyamide resin composition, those having an equivalent circular diameter [ D] of 300 nm or less is preferably contained in an amount of 20% or more, more preferably 35% or more, yet more preferably 50% or more,  
10 and most preferably 65% or more from the standpoints of improving the mechanical properties of the polyamide resin composition and reducing the warpage. The upper limit is not particularly limited but is preferably 100%.

In the polyamide resin composition of the present invention, the average of the equivalent circular diameters [ D] of the swelling mica is preferably 500 nm or less, more preferably 450 nm or less, yet more preferably 400 nm or less, and most preferably 350 nm or less from the standpoint of improving the mechanical properties of the polyamide resin composition, warpage reduction, and surface appearance of the resulting product. The lower limit is not particularly limited. Since no improvement occurs below 10 nm, there is no need to adjust the average equivalent circular diameter to below 10 nm.  
20  
25 The equivalent circular diameter [ D] may be determined

by obtaining a picture of a melt-mixed material, an injection-molded product, or a heat-pressed product using a microscope or the like, arbitrarily selecting from the picture a particular region containing 100 or more of layers 5 of swelling mica, and performing image processing using an image processor or the like so as to allow computer processing for quantitative determination.

Here, the number of the dispersed particles per unit weight ratio of the swelling mica found in an area of 100 10  $\mu\text{m}^2$  of the polyamide resin composition is defined as [ N] value. The [ N] value of the swelling mica in the polyamide resin composition of the present invention is preferably 30 or more, more preferably 45 or more, and most preferably 60 or more. The upper limit is not particularly limited. 15 However, the effect does not change at [ N] values exceeding about 1,000; thus, there is no need to increase the [ N] value to over 1,000.

For example, [ N] values are determined as follows: From a polyamide resin composition, a very thin slice 20 approximately 50 to 100  $\mu\text{m}$  in thickness is cut. A picture of the slice is taken by transmission electron microscopy (TEM) or the like, and the number of particles of the swelling mica found in a desired 100  $\mu\text{m}^2$  region in the picture is counted. The number is divided by the weight 25 ratio of the swelling mica used. Alternatively, the [ N]

value can be determined by selecting a desired region (whose area is measured in advance) containing more than 100 particles from a TEM micrograph, dividing the number of the swelling mica particles in that region by the weight ratio 5 of the swelling mica used, and converting the obtained value to a  $100 \mu\text{m}^2$  equivalent so as to define this converted value as the [ N] value. Thus, the [ N] values can be determined by using TEM micrographs or the like of the polyamide resin composition.

10       The average layer thickness is defined as the number-average value of the thickness of the layers of the dispersed lamellar swelling mica. Here, the upper limit of the average thickness of the swelling mica in the polyamide resin composition is preferably 50 nm or less, more 15 preferably, 45 nm or less, and most preferably 40 nm or less from the standpoint of improving the mechanical properties and the like of the polyamide resin composition. The lower limit of the average layer thickness is not particularly limited. However, since no change in effects occurs below 5 20 nm, there is no need to reduce the average layer thickness to 5 nm or less.

The maximum layer thickness is defined as the maximum thickness of the layers of the lamellar swelling mica dispersed in the polyamide resin composition of the present 25 invention. Here, the upper limit of the maximum layer

thickness is preferably 200 nm or less, more preferably 180 nm or less, and most preferably 150 nm or less from the standpoints of mechanical properties and surface appearance of the polyamide resin composition. The lower limit of the  
5 maximum layer thickness of the swelling mica is not particularly limited but is preferably at least 10 nm, more preferably at least 15 nm, and most preferably at least 20 nm.

The average aspect ratio is defined as the number-  
10 average of the ratio, layer length/layer thickness, of the swelling mica dispersed in the resin. The lower limit of the average aspect ratio of the swelling mica in the polyamide resin composition of the present invention is preferably 10, more preferably 20, and most preferably 30  
15 from the standpoint of improving mechanical properties and the like of the polyamide resin composition. Since the effect does not change at average aspect ratios exceeding 300, there is no need to increase the average aspect ratio to beyond 300. Thus, the preferable range of the average  
20 aspect ratio is 10 to 300.

The layer thickness and the layer length can be determined from a micrograph or the like of a film prepared by heat-press-molding or draw-molding a polyamide resin composition of the present invention melted by heating or  
25 from a picture of a thin product prepared by injection-

molding using a molten resin. In particular, assume that a film prepared as above or an injection-molded thin, flat specimen having a thickness of approximately 0.5 to 2 mm is placed on the X-Y plane. From this film or the specimen, a 5 very thin slice having a thickness of approximately 50 to 100  $\mu\text{m}$  is cut out along a plane parallel to the X-Z plane or the Y-Z plane, and this slice is observed at high magnifications of about  $\times 40,000$  to  $100,000$  or more by transmission electron microscopy or the like to determine 10 these values. Alternatively, these values can be determined by arbitrarily selecting a region containing 100 or more particles of the swelling mica from a TEM micrograph taken as in the above and performing the image processing to allow computer processing for quantitative determination.

15 Alternatively, a ruler or the like may be used for the determination.

The polyamide resin composition of the present invention may contain at least one of a styrene resin, an anhydride-containing olefin copolymer, and a carbon compound, 20 in addition to the polyamide resin and the swelling mica treated with the polyether compound described above.

First, the polyamide resin composition of the present invention containing a styrene resin in addition to the polyamide resin and the above-described swelling mica 25 treated with the polyether compound will be described below.

Addition of a styrene resin further improves the surface appearance (surface quality and low sink mark formation).

Examples of the styrene resins used in the present invention include, but are not limited to, polystyrene, 5 rubber-modified polystyrene (HIPS resin), styrene-acrylonitrile copolymers, and styrene-rubber polymer-acrylonitrile copolymers. Examples of the styrene-rubber polymer-acrylonitrile copolymers include acrylonitrile-butadiene-styrene (ABS) resins, acrylonitrile-ethylene-10 propylene-diene-styrene (AES) resins, acrylonitrile-acrylstyrene (AAS) resins, and acrylonitrile-chlorinated polyethylene-styrene (ACS) resins. These resins may be used alone or in combination.

Examples of the resins further include the above-15 described styrene resins having part of styrene and/or part or all of acrylonitrile substituted with a vinyl monomer copolymerizable with styrene. Examples of the vinyl monomer copolymerizable with styrene include  $\alpha$ -methylstyrene, p-methylstyrene, and p-tert-butylstyrene; (meth)acrylates such 20 as methyl (meth)acrylate, ethyl (meth)acrylate, propyl (meth)acrylate, and n-butyl (meth)acrylate; maleimide monomers such as maleimide, N-methylmaleimide, N-cyclohexylmaleimide, and N-phenylmaleimide; unsaturated carboxylic monomers such as acrylic acid, methacrylic acid, 25 maleic acid, fumaric acid, and itaconic acid. These resins

may be used alone or in combination.

ABS resins, polystyrenes, HIPS resins, AES resins, AAS resins, ACS resins, methacrylate-butadiene-styrene (MBS) resins, and the like are preferred. ABS resins and 5 polystyrenes each having part of styrene substituted with an unsaturated carboxylic monomer are more preferred, and ABS resins and polystyrenes substituted with methacrylic acid are most preferred.

The method of producing the styrene resins is not 10 particularly limited. A conventional method, such as mass polymerization, suspension polymerization, emulsion polymerization, or mass-suspension polymerization, may be employed.

The styrene resin used in the present invention is not 15 particularly limited as long as the effect of the present invention is not diminished. From the standpoints of providing a polyamide resin composition that can achieve a good balance between various physical properties, compatibility with the polyamide, and the economy, a 20 particularly preferable example of the ABS resin modified by unsaturated carboxylic acid is one prepared by mixing an unsaturated carboxylic acid-containing copolymer, which contains 40 to 80 percent by weight of an aromatic vinyl compound, 15 to 50 percent by weight of a vinyl cyanide 25 compound, 0.1 to 20 percent by weight of an unsaturated

carboxylic compound, and 0 to 30 percent by weight of another copolymerizable vinyl compound, with 70 to 5 percent by weight of a graft-copolymerizable vinyl compound in the presence of 30 to 95 percent by weight of a diene rubber  
5 having an average particle diameter of 0.01 to 5.0  $\mu\text{m}$ .

When the content of the aromatic vinyl compound in the unsaturated carboxylic acid-containing copolymer used in making the unsaturated carboxylic acid-modified ABS resin exceeds 80 percent by weight, resistance to chemicals and  
10 impacts may decrease. At a content less than 40 percent by weight, the formability may decrease. When the content of the vinyl cyanide compound exceeds 50 percent by weight, the thermal stability during forming may decrease or coloring may occur by heating. At a content less than 15 percent by  
15 weight, resistance to chemicals and impact may decrease.

When the content of the unsaturated carboxylic acid compound exceeds 20 percent by weight, the thermal stability during forming may decrease or coloring may occur by heating. At a content less than 0.1 percent by weight, the compatibility  
20 with the polyamide cannot be easily achieved, and exfoliation may occur at the surface of the resulting product. When the content of the other copolymerizable vinyl monomer exceeds 30 percent by weight, it may not be possible to achieve a satisfactory balance between the heat  
25 resistance and the impact resistance.

Examples of the aromatic vinyl compound used in the unsaturated carboxylic acid-containing copolymer include styrene,  $\alpha$ -methylstyrene, chlorostyrene, and methylstyrene. From the standpoint of improving the heat resistance, use of 5  $\alpha$ -methylene is particularly preferable. Examples of the vinyl cyanide compound include acrylonitrile and methacrylonitrile. Examples of the unsaturated carboxylic acid compound include acrylic acid and methacrylic acid.

Examples of the other copolymerizable vinyl compound include 10 alkyl esters of methacrylic acid and acrylic acid, such as methyl methacrylate, ethyl methacrylate, methyl acrylate, and ethyl acrylate; and maleimide compounds such as maleimide and phenylmaleimide. The above-described aromatic vinyl compound, vinyl cyanide compound, unsaturated carboxylic acid compound, and other copolymerizable vinyl 15 compound may each be used alone or in combination.

For example, the unsaturated carboxylic acid-containing copolymer can be produced as follows: First,  $\alpha$ -methylstyrene, water, and an emulsifier are charged in 20 advance to prepare an appropriate emulsion. To the emulsion, acrylonitrile and other monomers are continuously added dropwise in minute amounts so that there is always large excess of  $\alpha$ -methylstyrene, i.e., at least 80 percent by weight and preferably at least 90 percent by weight of  $\alpha$ -methylstyrene, in the polymerization system, thereby 25

yielding a target copolymer. Here, the unsaturated carboxylic compound may be charged in advance with  $\alpha$ -methylstyrene or may be mixed with acrylonitrile and added.

It is also possible to charge additional unsaturated

5 carboxylic acid compound in portions after the unsaturated carboxylic acid compound is charged in advance. Moreover, addition of part of  $\alpha$ -methylstyrene is also possible. In such a case, the amount of the  $\alpha$ -methylstyrene charged in advance is preferably 50 to 90 percent by weight relative to

10 100 percent by weight of the entirety of the monomers from the standpoints of chemical resistance, impact resistance, and thermal deformation resistance.

A graft copolymer prepared by graft-copolymerizing 70 to 5 percent by weight of a graft-copolymerizable vinyl

15 compound in the presence of 30 to 95 percent by weight of a diene rubber having an average particle diameter in the range of 0.01 to 5.0  $\mu\text{m}$  is suitable for use.

Aromatic vinyl compounds, vinyl cyanide compounds, unsaturated carboxylic acid compounds, and other

20 copolymerizable vinyl compounds may be used as the graft-copolymerizable vinyl compound. Examples of these are the same as those described above used in the unsaturated carboxylic acid-containing copolymer. These may be used alone or in combination.

25 At a diene rubber content exceeding 95 percent by

weight, the impact resistance and the oil resistance may decrease. At a diene rubber content less than 30 percent by weight, the impact resistance may decrease. An example of the diene rubber is butadiene.

5       A diene rubber having an average particle diameter of 0.01 to 5.0  $\mu\text{m}$  is preferably used in the graft copolymer from the standpoint of the impact resistance of the polyamide resin composition and the surface appearance of the resulting product. A diene rubber having an average  
10      particle diameter of 0.02 to 2.0  $\mu\text{m}$  is particularly preferable. Furthermore, a diene rubber latex in which small-particle diene rubber latex is coagulated may be used to increase the impact strength. The small-particle diene rubber latex may be coagulated by a conventional method, for  
15      example, a method of adding an acidic substance (Japanese Examined Patent Application Publication Nos. 42-3112, 55-19246, and 2-9601 and Japanese Unexamined Patent Application Publication Nos. 63-117005, 63-132903, 7-157501, and 8-259777); or a method of adding an acid radical-containing  
20      latex (Japanese Unexamined Patent Application Publication Nos. 56-166201, 59-93701, 1-126301, 8-59704, and 9-217005), but the method is not particularly limited.

25      The unsaturated carboxylic acid-containing copolymer and the graft copolymer are preferably produced by emulsion polymerization, but the method is not limited to emulsion

polymerization. For example, mass polymerization,  
suspension polymerization, solution polymerization, or any  
combination of these, i.e., emulsion-suspension  
polymerization or emulsion-mass polymerization may be  
5 employed. The emulsion polymerization may be conducted  
according to a conventional method. That is, the compounds  
described above may be reacted in an aqueous medium in the  
presence of a radical initiator. In such a case, the  
compounds may be used as a mixture or, if necessary, may be  
10 used separately. The compounds may be added in one step or  
may be consecutively added in portions, but the method of  
adding the compounds is not particularly limited. Examples  
of the radical initiator include water- or oil-soluble  
peroxides such as potassium persulfate, ammonium persulfate,  
15 cumen hydroperoxide, and paramethane hydroperoxide. These  
may be used alone or in combination. Appropriate  
polymerization accelerators, polymerization degree adjustors,  
and emulsifiers used in conventional emulsion polymerization  
may also be used.

20 A conventional method may be employed to obtain a dry  
resin from the resulting latex. In such a case, a dry resin  
may be obtained after mixing the unsaturated carboxylic  
acid-containing copolymer and the latex of the graft  
copolymer; alternatively, resins may be separately prepared  
25 and then mixed in the form of powder. As the method for

obtaining a resin from a latex, a method in which an acid,  
such as hydrochloric acid, sulfuric acid, or acetic acid, or  
a metal salt, such as calcium chloride, magnesium chloride,  
or aluminum sulfate, is added to a latex to coagulate the  
5 latex, followed by dehydration and drying of the latex may  
be employed. The resulting mixed resin containing the  
unsaturated carboxylic acid-containing copolymer and the  
graft copolymer exhibits high compatibility with the  
polyamide resin while maintaining the inherent properties of  
10 the ABS resin.

The ratio (parts by weight) of the polyamide resin to  
the styrene resin used in the present invention is not  
particularly limited. From the standpoint of achieving a  
balance between different properties such as heat resistance  
15 and impact resistance, the ratio of the polyamide resin to  
the styrene resin is preferably 95:5 to 5:95, more  
preferably, 90:10 to 30:70, and most preferably 85:15 to  
45:55.

In the polyamide resin composition of the present  
20 invention, the dispersion state of the swelling mica differs  
depending on the polarity of the polyamide resin and the  
styrene resin, the type of swelling mica, and the type of  
polyether compound. The number density of the swelling mica  
may be uniform among the respective resin phases, may be  
25 higher in the polyamide phase than in the styrene resin

phase, or may be higher in the styrene resin phase than in the polyamide phase. In order to achieve a balance between heat resistance and mechanical properties, the density of the dispersed swelling mica is preferably higher in the 5 polyamide resin phase of the polyamide resin composition.

The polyamide resin composition of the present invention may contain an anhydride-containing olefin copolymer in addition to the polyamide resin and the swelling mica treated with the polyether compound described 10 above. According to this arrangement, for example, water absorption of the polyamide resin can be reduced.

The anhydride-containing olefin copolymer is obtained by copolymerization or graft polymerization of olefin or an olefin copolymer with an alicyclic dicarboxylic anhydride 15 having a cis double bond in the ring or an  $\alpha,\beta$ -unsaturated dicarboxylic anhydride.

Examples of the olefin or olefin copolymer include homopolymers of olefins such as polyethylene, polypropylene, and polybutene; copolymers of different olefins such as 20 ethylene-propylene copolymers, ethylene-butene copolymers, propylene-butene copolymers, and ethylene-propylene-diene copolymers; and copolymers of olefins and different monomers.

Examples of the different monomers include  $\alpha,\beta$ -unsaturated carboxylates, e.g., methacrylates such as methyl 25 methacrylate, ethyl methacrylate, butyl methacrylate, 2-

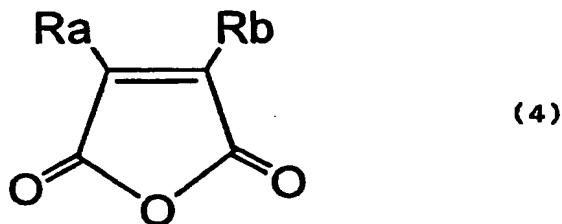
ethylhexyl methacrylate, and 2-hydroxyethyl methacrylate, and acrylates such as ethyl acrylate, butyl acrylate, 2-ethylhexyl acrylate, and 2-hydroxyethyl acrylate; styrenic compounds such as styrene,  $\alpha$ -methylstyrene, and  
5 vinyltoluene;  $\alpha,\beta$ -unsaturated nitriles such as acrylonitrile and methacrylonitrile;  $\alpha,\beta$ -unsaturated carboxylic acids such as acrylic acid and methacrylic acid; vinyl acetate and vinyl ether; and mixtures of these. These may also be copolymerized if necessary.

10       The above-described copolymer may be a random copolymer, a block copolymer, a graft copolymer, or an alternating copolymer. Among these copolymers, an ethylene-propylene copolymer, an ethylene-butene copolymer, an ethylene-vinyl acetate copolymer, an ethylene-ethyl acrylate copolymer, an  
15       ethylene-methyl methacrylate copolymer, and an ethylene-propylene-diene copolymer are particularly preferable from the standpoints of yielding toughness, cost, and handling ease. The polyolefins described above may be used in combination of two or more.

20       Examples of the alicyclic dicarboxylic anhydride having a cis double bond in the ring include anhydrides of cis-4-cyclohexene-1,2-dicarboxylic acid, endo-bicyclo-(2,2,1)-5-heptene-2,3-dicarboxylic acid, methyl-endo-cis-bicyclo-(2,2,1)-5-heptene-2,3-dicarboxylic acid, and endo-bicyclo-  
25       (2,2,1)-1,2,3,4,7,7-hexachloro-2-heptene-5,6-dicarboxylic

acid. From the standpoint of yielding toughness, endo-bicyclo-(2,2,1)-5-heptene-2,3-dicarboxylic anhydride is preferred. In some cases, their derivatives, e.g., dicarboxylic acids, dicarboxylic metal salts, esters, amides, 5 and acid halides, may be used.

The  $\alpha,\beta$ -unsaturated dicarboxylic anhydride is represented by general formula (4):



(wherein Ra and Rb each represent a hydrogen atom, an alkyl 10 group, an alkenyl group, an alkynyl group, or a halogen atom; Ra and Rb may form a cyclic group with the adjacent carbon atoms; and the bond between the adjacent atoms of Ra and Rb may be a single bond instead of a double bond).

Examples of such compound include maleic anhydride, 15 methylmaleic anhydride, chloromaleic anhydride, butynylsuccinic anhydride, and tetrahydrophthalic anhydride.

In the anhydride-containing olefin copolymer used in the present invention, the lower limit of the ratio of the alicyclic dicarboxylic anhydride having a cis double bond in 20 the ring or the  $\alpha,\beta$ -unsaturated dicarboxylic anhydride for copolymerization or graft reaction is preferably 0.05 mol%, more preferably 0.1 mol%, and most preferably 0.2 mol% to

100 mol% of the olefin or olefin copolymer from the standpoint of yielding toughness. The upper limit of the ratio for the copolymerization or the graft reaction is preferably 80 mol%, more preferably 50 mol%, and most 5 preferably 30 mol% from the stand point of the processability.

The anhydride-containing olefin copolymer may be produced by a typical conventional radical copolymerization. Alternatively, it may be produced by radical graft reaction 10 of an olefin homopolymer or an olefin copolymer with at least one of the above-described different monomers in the presence of a radical generator and in the presence or absence of a solvent or a dispersion medium. In particular, when graft reaction is conducted in a molten state, the 15 copolymer can be efficiently produced by using a melt mixer, such as an extruder or a kneader.

The lower limit of the amount of the anhydride-containing olefin copolymer added to the 100 parts by weight of the polyamide resin is preferably 1 part by weight, more 20 preferably 2 parts by weight, and most preferably 3 parts by weight from the standpoint of suppressing water absorption. The upper limit is preferably 50 parts by weight, more preferably 30 parts by weight, yet more preferably 20 parts by weight, and most preferably 15 parts by weight from the 25 standpoints of formability and stiffness.

The weight ratio of the anhydride-containing olefin copolymer in the polyamide resin composition is preferably in the range of 1 to 30 percent by weight.

The polyamide resin composition of the present invention may contain a carbon compound in addition to the polyamide resin and the swelling mica treated with the polyether compound described above. In this manner, antistatic properties can be yielded.

The carbon compound used in the present invention is not particularly limited and may be any commercially available product other than carbon fibers. From the standpoint of the surface quality, warpage, deformation, and the like of the resulting product, the carbon compound is preferably in the form of particles or fine fibrils. The carbon compound preferably has electric conductivity.

Examples of the carbon compound in the form of particles include acetylene black and various furnace carbon blacks having electric conductivity. Various commercially available products may be used. An example is Ketjenblack (registered trade mark) produced by KetjenBlack International. Examples of the carbon compound in the form of fine fibrils include fibrous carbon compounds having a diameter of approximately 3.5 to 75 nm, a.k.a., carbon nanotubes. Various commercially available carbon nanotubes may be used. An example is Hyperion (registered trade mark)

produced by Hyperion Catalysis International. These may be used alone or in combination.

The lower limit of the amount of the carbon compound added to 100 parts by weight of the polyamide resin is 5 preferably 0.5 parts by weight, more preferably 1.0 part by weight, and most preferably 1.5 parts by weight from the standpoint of conductivity. The upper limit of the carbon compound added is preferably 12 parts by weight, more preferably 11 parts by weight, and most preferably 10 parts 10 by weight from the standpoint of pelletization of the resin composition by extrusion and mechanical strength.

The method for producing the polyamide resin composition of the present invention is not particularly limited. For example, the polyamide resin composition may 15 be made by melt-mixing the polyamide resin and the swelling mica treated by the polyether compound using various types of conventional mixers. In the event of adding at least one selected from the styrene resin, the anhydride-containing olefin copolymer, and the carbon compound, the components 20 may be melt-mixed in the same manner to produce the polyamide resin composition.

The temperature for the melt-mixing process is not particularly limited but is preferably 200°C to 360°C and more preferably 200°C to 300 °C.

25 Examples of the mixer include single-shaft extruders,

twin-shaft extruders, rollers, banbury mixers, and kneaders. Mixers having high shear efficiency are particularly preferable. The polyamide resin, the swelling mica treated with the polyether compound, and the individual components 5 added as required may be simultaneously placed in the above-described mixer. Alternatively, the polyamide resin may be melted in advance and then melt-mixed with the swelling mica.

If necessary, the polyamide resin composition of the present invention may contain polybutadiene, a butadiene-10 styrene copolymer, acryl rubber, ionomer, an ethylene-propylene copolymer, an ethylene-propylene-diene copolymer, natural rubber, chlorinated butyl rubber, an  $\alpha$ -olefin homopolymer, a copolymer of two or more  $\alpha$ -olefins (the copolymer may be a random copolymer, a block copolymer, a 15 graft copolymer, or the like, or may be a mixture of these), and an impact resistance improver such as an olefin elastomer. These may be modified by an acid compound such as maleic anhydride or an epoxy compound such as glycidyl methacrylate.

20 As long as the mechanical properties and the like are not adversely affected, any other thermoplastic resin or thermosetting resin may be used. Examples thereof include unsaturated polyester resins, polyester carbonate resins, liquid crystalline polyester resins, polyolefin resins, 25 thermoplastic polyester resins, rubber polymer-reinforced

styrene resins, polyphenylene sulfide resins, polyphenylene ether resins, polyacetal resins, polysulfone resins, and polyarylate resins. These may be used alone or in combination.

5       Depending on the purpose, various additives, such as pigments and dyes, a heat stabilizer, an antioxidant, a UV absorber, a photostabilizer, a lubricant, a plasticizer, a flame retarder, and an antistatic agent, may be added.

The polyamide resin composition of the present  
10 invention is suitable for injection molding and heat-press molding and can be used in blow molding. The resulting product has excellent appearance, satisfactory mechanical properties, and high resistance to thermal deformation. Thus, for example, the composition is suitable for use in  
15 automobile parts, parts for home appliances, domestic houseware, wrapping materials, and other general industrial materials.

The polyamide resin composition containing the anhydride-containing olefin copolymer is particularly  
20 suitable for products prepared by injection molding. The resulting products have excellent heat stability, surface quality, and stiffness, and do not greatly change their properties by water absorption. Thus, the composition is suitable for use in automobile exterior components such as a  
25 front fender, a rear fender, a hood bulge, a side garnish, a

rear garnish, a backdoor panel, and a wheel cap. When the composition is used in a front fender, a rear fender, a hood bulge, a side garnish, a rear garnish, and a backdoor panel among the automobile exterior components described above,

5 the composition is preferably used in sections that affect the appearance. Moreover, when the composition is used in a wheel cap, the composition is preferably used in the entire wheel cap. However, the use of the composition is not limited to these.

10 The polyamide resin composition containing the carbon compound is particularly suitable for use in a product made by injection molding. The resulting product has electric conductivity and antistatic property and suffers little from anisotropy that leads to mold shrinkage. Thus, warpage is

15 small even when a complex-shaped product is made by injection molding. Moreover, the stiffness and the heat resistance are excellent without lowering the surface quality of the polyamide resin. Thus, the composition is suitable for use in electrostatic recording sheets; housings

20 for electronic devices; electrostatic containers; electrostatic films; floor coverings, wall materials, and partitions for clean rooms; covering materials for electronic devices; magazines for ICs and the like; head gimbal assemblies; antistatic transfer trays for HDD internal

25 components such as sliders and slider arms; HDD internal

components such as containers for seeking arms; and antistatic transfer trays for other electronic components, for example.

5 Best Mode For Carrying Out the Invention

The present invention will now be described in detail with reference to the examples below; however, the present invention is not limited to these examples.

Below is a summary list of the primary materials used 10 in EXAMPLES and COMPARATIVE EXAMPLES. Note that these materials were not purified unless otherwise noted.

(Materials)

- Polyamide resin A1 (Nylon 6): Unitika Nylon 6 A1030BRL (product of Unitika Ltd.)
- Polyamide resin A2 (Nylon 66): Unitika Nylon 66 A125N (product of Unitika Ltd.)
- Polyamide resin A3 (Nylon 46): Stanyl TS300 (product of DSM-JSR)
- Polyamide resin A4 (Nylon MXD6): Reny 6002 (product of 20 Asahi Kasei Corporation)
- Styrene resin B1 (ABS resin): resin prepared by the method described in REFERENCE EXAMPLE 1 below
- Styrene resin B2 (styrene-methacrylic acid copolymer): G-9001 (product of Asahi Kasei Corporation)
- Polyphenylene ether (PPE) resin: IUPIACE YPX-100L (product 25

of Mitsubishi Engineering-Plastics Corporation)

- Anhydride-containing olefin copolymer C1: Bondine AX8930 (product of Sumitomo Chemical Co., Ltd.) (polyolefin copolymer with maleic anhydride)

5    • Anhydride-containing olefin copolymer C2: Tafmer MH7020 (product of Mitsui Chemicals) (polyolefin copolymer with maleic anhydride)

- Anhydride-containing olefin copolymer C3: Tuftec M1943 (product of Asahi Kasei Corporation) (polyolefin copolymer with maleic anhydride)

10    • Swelling mica E1: Somasif ME100 (product of Co-op Chemical Co., Ltd.)

- Polyether compound F1: BISOL 18EN (product of Toho Chemical Industry Co., Ltd.)

15    • Polyether compound F2: BISOL 20PN (product of Toho Chemical Industry Co., Ltd.)

- Carbon compound G1: Ketjenblack (product of KetjenBlack International)
- Carbon compound G2: master batch pellets containing PA6 and a fibril carbon material dispersed in PA6 at a concentration of 20%, product name MB4020-00 (product of Hyperion Catalysis International)

20    • Carbon compound G3: master batch pellets containing PA66 and a fibrous carbon material dispersed in PA66 in a concentration of 20%, product name MB4620-00 (product of

Hyperion Catalysis International)

The methods for determining various properties in EXAMPLES and COMPARATIVE EXAMPLES will now be described.

5

(Determining Dispersion State)

Dispersion state was determined using an ultrathin section 50 to 100  $\mu\text{m}$  in thickness obtained by a frozen section technique. The section was observed with a 10 transmission electron microscope (JEM-1200EX, product of JEOL) with an accelerating voltage of 80 kV at a magnification of 40,000 to 1,000,000 to obtain a micrograph of the dispersion state of swelling mica. From this TEM 15 micrograph, a region containing 100 or more of dispersed particles was arbitrarily selected. The layer thickness, the layer length, and the number of particles ( $[N]$  values) were determined either manually with a graduated ruler or by processing the micrograph with Image Analyzer PIAS III produced by Inter Quest Co., Ltd.

20 The equivalent circular diameter [ $D$ ] was determined with Image Analyzer PIAS III produced by Inter Quest Co., Ltd.

The  $[N]$  values were determined as follows. First, the 25 number of particles of the swelling mica present in the selected region in the TEM micrograph was determined. The

ash content of the resin composition derived from the swelling mica was separately determined. The number of the particles was divided by the ash content and the result was converted to a number per  $100 \mu\text{m}^2$  area. The number-average  
5 value of the layer thickness of the swelling mica was assumed as the average layer thickness; and the maximum value among the layer thickness of the swelling mica was assumed as the maximum layer thickness. A sample containing large dispersed particles and thus not suitable for  
10 observation by TEM was examined using an optical microscope (Optical microscope BH-2 produced by Olympus Optical Co., Ltd.), and the [ N] values were determined as is described above. Where required, a sample was melted at  $250^\circ\text{C}$  to  $270^\circ\text{C}$  using Hotstage THM 600 produced by Linkam Scientific  
15 Instruments Ltd., and the state of the dispersed particle was observed in a molten state. The number-average value of the ratios of layer length to layer thickness of the individual swelling mica particles was assumed as the average aspect ratio. For dispersed particles that were not  
20 lamellar, the aspect ratio was determined as the ratio, major axis/minor axis. Here, a "major axis" is the long side of a hypothetic rectangle having the minimum area among hypothetic rectangles circumscribed with a target particle in a micrograph, and a "minor axis" is the short side of  
25 this hypothetic rectangle.

(Flexural Properties)

The polyamide resin composition of the present invention was dried (90°C, 10 hours). Using an injection molding machine operating at a clamping pressure of 75 t, a specimen having dimensions of approximately 10 × 100 × 6 mm was formed by injection molding at a resin temperature in the range of 240°C to 300°C (Nylon 6: 240°C, Nylon 66: 260°C, Nylon MXD6: 280°C, Nylon 46: 300°C). The flexural strength and the flexural elastic modulus of the specimen were measured according to ASTM D-790.

(Deflection Temperature Under Load)

The deflection temperature under load was determined according to ASTM D-648 under a load of 1.86 MPa by using the same type of specimen used in determining the flexural properties.

(Warpage)

The polyamide resin composition of the present invention was dried (90°C, 10 hours). A tabular specimen having dimensions of approximately 120 × 120 × 1 mm was formed by injection molding at a resin temperature in the range of 240°C to 300°C (Nylon 6: 240°C, Nylon 66: 260°C, Nylon MXD6: 280°C, Nylon 46: 300°C). The tabular specimen was placed on a flat surface, and one of the four corners was held down. Of the remaining three corners, one most distant from the flat surface was determined by measuring

the distance with a slide caliper. The same was repeated for every corner, and the obtained warpages were averaged.

(Mold Shrinkage Rate)

The polyamide resin composition of the present invention was dried (90°C, 10 hours). A tabular specimen having dimensions of approximately 120 × 120 × 2 mm was formed by injection molding at a resin temperature in the range of 240°C to 300°C (Nylon 6: 240°C, Nylon 66: 260°C, Nylon MXD6: 280°C, Nylon 46: 300°C). The mold shrinkage rate was determined by the following equation:

$$\text{Mold shrinkage rate (\%)} = (\text{size of die} - \text{observed size of molded product}) / (\text{size of die}) \times 100$$

In the table below, MD denotes the direction of the resin flow, and TD denotes a direction orthogonal to the resin flow.

(Centerline Average Roughness)

The centerline average roughness was determined with surface analyzer Surfcom 1500A produced by Tokyo Seimitsu Co., Ltd., using the same type of specimen used in determining the mold shrinkage rate.

(Ash Content)

The ash content of the polyamide resin composition derived from the swelling mica was determined according to JIS K 7052.

25 (Method B Flow)

The polyamide resin composition of the present invention was dried (90°C, 10 hours). The method B flows after 5 minutes and after 15 minutes were determined using a flow tester produced by Shimadzu Corporation at a 5 temperature of 280°C under a load of 100 kg. The melt stability is higher when the difference between the flow after 5 minutes and the flow after 15 minutes is smaller.

(Sink Mark Evaluation)

The polyamide resin composition of the present 10 invention was dried (90°C, 10 hours). Injection molding was performed at a resin temperature in the range of 240°C to 280°C (Nylon 6: 240°C, Nylon 66: 260°C, Nylon MXD6: 280°C) to prepare a sample constituted from a circular plate having a diameter of approximately 100 mm and a thickness of 15 approximately 2.5 mm and six ribs disposed on one face of the circular plate and arranged to radiate from the center of the circular plate, the six ribs respectively having dimensions of 0.8, 1.0, 1.2, 1.4, 1.6, and 1.8 × 35 × 10 mm. The face of the sample not provided with the ribs was 20 visually observed to determine the occurrence of any sink mark. Sink marks are recesses on the surface caused by thickness deviation and shrinkage of resin during molding and impair the surface appearance. The assessment was provided in terms of the thickness of the ribs that did not 25 generate sink marks. The larger the thickness of the rib,

the more likely that the sink marks will occur.

(Water Absorption)

The polyamide resin composition of the present invention was dried (90°C, 10 hours). Subsequently, an ASTM No. 1 dumbbell specimen was prepared at a resin temperature in the range of 240°C to 280°C (Nylon 6: 240°C, Nylon 66: 260°C, Nylon MXD6: 280°C). The specimen was placed in distilled water at 23°C for 24 hours, and the water absorption was measured according to the method set forth in JIS K7209.

(Warpage Upon Water Absorption)

The polyamide resin composition of the present invention was dried (90°C, 10 hours). Subsequently, a tabular specimen having dimensions of approximately 120 × 120 × 1 mm was prepared by injection molding at a resin temperature in the range of 240°C to 260°C (Nylon 6: 240°C, Nylon 66: 260°C). After the specimen was placed in water at 23°C for 24 hours, the warpage was measured. The specimen was placed on a flat surface, and one of the four corners of the specimen was held down. Of the remaining three corners, one most distant from the flat surface was determined by measuring the distance with a slide caliper. The same was repeated for every corner, and the obtained values were averaged.

(Surface Quality)

The surface roughness of the specimen was measured with a three dimensional, imaging surface structure analyzer (Zygo New View 5030 produced by Zygo Corporation).  
(Melt Heat Stability)

5       The polyamide resin composition of the present invention was dried (90°C, 10 hours). Using a flow tester produced by Shimadzu Corporation, the Method B flows were measured after 5 minutes and after 15 minutes at 260°C under a load of 100 kg. Simultaneously, color development was  
10 visually observed. The smaller the difference between the flows after 5 minutes and 15 minutes, the higher the melt heat stability.

(Volume Resistivity)

The volume resistivity was determined with resistance  
15 meter R8340A produced by Advantest Corporation using the same type of specimen used in determining mold shrinkage rate. The volume resistivity was measured after the specimen was allowed to stand at 25°C and 50%RH for 24 hours.

(SYNTHETIC EXAMPLE 1)

20       Ion-exchange water, polyether compounds, and swelling mica at the weight ratios set forth in Table 1 were mixed for 15 to 30 minutes. The mixture was then dried and powdered to prepare swelling mica (Clays J-1 to J-6) treated with the polyether compounds.

Table 1

	Clay J-1	Clay J-2	Clay J-3	Clay J-4	Clay J-5	Clay J-6
Water	100	100	100	100	100	100
Swelling mica E1	8	8	8	8	8	8
Polyether compound F1	4	1.6	0.8		0.8	
Polyether compound F2				2.5	1.6	4

(unit: parts by weight)

(SYNTHETIC EXAMPLE 2)

5        Ion-exchange water, swelling mica, polyvinylpyrrolidone  
(PVP), methylstearyl bis[PEG] ammonium chloride (Ethoquad  
produced by Lion Akzo Co., Ltd.), and trioctylmethylammonium  
chloride at the weight ratios set forth in Table 2 were  
mixed for 15 to 30 minutes. Subsequently, the mixture was  
10 dried and powdered (Clays K-1 to K-4).

Table 2

	Clay K-1	Clay K-2	Clay K-3	Clay K-4
Water	100	100	100	100
Swelling mica E1	8	8	8	8
Polyvinylpyrrolidone	4			
Methylstearyl bis[PEG] ammonium chloride		8		
Trioctylmethylammonium chloride			4	6

(unit: parts by weight)

(EXAMPLES 1 and 2 and COMPARATIVE EXAMPLES 1 to 4)

Polyamide resin A1, the swelling mica prepared in SYNTHETIC EXAMPLE 1, the swelling mica prepared in SYNTHETIC EXAMPLE 2, and swelling mica E1 at the weight ratios set forth in Table 3 were melt-mixed using a twin shaft extruder 5 (TEX 44 produced by Japan Steel Works, Ltd.) while adjusting the temperature to the dies to 220°C to 250°C from the initial stage of the mixing. The physical properties of the resulting polyamide resin compositions were evaluated. The results are shown in Table 3.

10 Table 3 shows that the swelling mica treated with PVP or ammonium salts did not exhibit sufficient reinforcing effect. Moreover, the warpage and the mold shrinkage were not significantly improved, and deterioration at the processing temperature was significant.

15 (COMPARATIVE EXAMPLE 5)

To a pressure reactor, 5,000 g of  $\epsilon$ -caprolactam, 1,100 g of water, and 550 g of swelling mica were placed, and heated to 250°C while stirring. The pressure inside the reactor was increased to 4 kg/cm<sup>2</sup> to 15 kg/cm<sup>2</sup> while releasing steam. 20 The pressure was then reduced to about 2 kg/cm<sup>2</sup> and the temperature was increased to about 260°C. Under these conditions, polymerization for a polyamide composition containing approximately 10% of swelling mica was attempted. In the midst of the reaction, the motor load current of the 25 mixer of the reactor became unstable, which eventually led

to mixing failure due to overload. Thus, the polymerization was discontinued. In other words, an attempt was made to obtain a polyamide composition by polymerization but failed due to an increased melt viscosity.

Table 3

The descriptions of the reference symbols in the tables above are as follows:

\*: Significant deterioration occurred during the melt processing; thus, no specimen usable in measurement was obtained.

5            \*\*: Measurement was not possible due to severe deterioration.

      \*\*\*: The mixer motor of the reactor was overloaded due to an increase in the melt viscosity, and the polymerization was thus discontinued.

10      (\*1): Because dispersed particles were not lamellar, the ratio, major axis/minor axis, of the dispersed particles was determined.

      (\*2): Because dispersed particles were not lamellar, the number-average value of the minor axes of the dispersed particles was determined.

15      (\*3): Because dispersed particles were not lamellar, the maximum value of the minor axis of the dispersed particles was determined.

(COMPARATIVE EXAMPLES 6 to 8)

20      Polyamide resin A1, talc, mica, and a glass fiber reinforcing material at the weight ratios set forth in Table 4 were melt-mixed as in EXAMPLE 1 to prepare polyamide resin compositions. The properties thereof were evaluated. The results are shown in Table 4.

Table 4

		COMPARATIVE EXAMPLES		
		6	7	8
Polyamide resin A1	Parts by weight		100	
Talc		11	11	11
Mica				
Glass fibers				
Ash content	wt%	10.0	9.9	9.9
Ratio of [ D] ≤ 300 nm	%	0	0	Not measured
Average [ D]	nm	2420	2580	Not measured
Number of dispersed particles [ N]	no./wt% · 100 μm <sup>2</sup>	5	2	Not measured
Average aspect ratio	-	1.5 (*1)	1.5 (*1)	Not measured
Average layer thickness	nm	App. 3,000 (*2)	App. 3,000 (*2)	Not measured
Maximum layer thickness	nm	App. 90,000 (*3)	App. 90,000 (*3)	Not measured
Flexural elastic modulus	MPa	3010	4250	5400
Flexural strength	MPa	95	120	130
Deflection temperature under load	°C	72	90	148
Warpage	mm	7.8	7.1	14.2
Mold shrinkage rate	%			
MD		1.43	1.40	0.56
TD		1.59	1.55	1.78
Centerline average roughness	nm	210	430	690

(\*1): Because dispersed particles were not lamellar, the ratio, major axis/minor axis, of the dispersed particles was determined.

(\*2): Because dispersed particles were not lamellar, the number-average value of the minor axes of the dispersed particles was determined.

(\* 3): Because dispersed particles were not lamellar, the maximum value of the minor axis of the dispersed particles was determined.

5       Table 4 shows that neither talc nor mica conventionally used exhibited a sufficient reinforcing effect. Moreover, the warpage and the mold shrinkage were not significantly improved, and the surface quality was degraded. Although the reinforcing effect could be achieved by adding the glass  
10 fibers, this adversely affected the warpage and the surface quality. Thus, none of COMPARATIVE EXAMPLES 6 to 8 achieved a satisfactory balance.

(EXAMPLES 3 to 6)

Polyamide resin A1 and the swelling mica obtained in  
15 SYNTHETIC EXAMPLE 1 at the weight ratios set forth in Table 5 were melt-mixed using a twin shaft extruder (TEX 44 produced by Japan Steel Works, Ltd.) as in EXAMPLE 1 to obtain polyamide resin compositions. The properties of the compositions were evaluated, and the results are shown in  
20 Table 5.

Table 5

	Parts by weight	EXAMPLES			
		3	4	5	6
Polyamide resin A1			100		
Clay J-2		5	7.8	20	30
Ash content	wt%	4.0	6.0	13.9	19.2
Ratio of [ D] ≤ 300 nm	%	90	90	80	65
Average [ D]	nm	103	104	140	168
Number of dispersed particles [ N]	no./wt% · 100 μm <sup>2</sup>	135	135	112	85
Average aspect ratio	-	138	140	102	82
Average layer thickness	nm	8.3	8.5	11	13
Maximum layer thickness	nm	34	33	48	65
Flexural elastic modulus	MPa	4010	4850	6650	8030
Flexural strength	MPa	118	123	130	132
Deflection temperature under load	°C	108	131	160	182
Warpage	mm	2.5	1.9	1.0	0.6
Mold shrinkage rate	%				
MD		0.67	0.54	0.29	0.19
TD		0.68	0.59	0.32	0.20
Centerline average roughness	nm	3.8	3.8	4.3	5.7

(EXAMPLES 7 to 11)

Polyamide resin A2 and the swelling mica obtained in  
 5 SYNTHETIC EXAMPLE 1 at the weight ratios set forth in Table  
 6 were melt-mixed using a twin shaft extruder (TEX 44  
 produced by Japan Steel Works, Ltd.) while adjusting the  
 temperature to the dies to 230°C to 260°C from the initial  
 stage of the mixing. The physical properties of the  
 10 resulting polyamide resin compositions were evaluated. The  
 results are shown in Table 6.

Table 6

		EXAMPLES				
		7	8	9	10	11
Polyamide resin A2	Parts by weight	100				
Clay J-1		16	13	28	11	14
Clay J-2						
Clay J-3						
Clay J-4						
Ash content	wt%	9.3	9.5	18.1	9.1	9.4
Ratio of [ D] ≤ 300 nm	%	92	80	70	69	35
Average [ D]	nm	108	145	165	201	417
Number of dispersed particles [ N]	no./wt% · 100 μm <sup>2</sup>	140	100	92	80	46
Average aspect ratio	-	143	105	95	88	51
Average layer thickness	nm	7.8	10.5	12.5	14.5	34.5
Maximum layer thickness	nm	30	50	58	65	152
Flexural elastic modulus	MPa	5900	5600	7990	5550	4850
Flexural strength	MPa	125	115	131	115	91
Deflection temperature under load	°C	148	140	178	138	123
Warpage	mm	1.0	1.0	0.5	1.2	3.7
Mold shrinkage rate	%					
MD		0.25	0.30	0.16	0.36	0.67
TD		0.27	0.33	0.17	0.40	0.70
Centerline average roughness	nm	3.7	4.1	5.2	4.0	7.0

(COMPARATIVE EXAMPLE 9 to 11)

Polyamide resin A2, talc, mica, and a glass fiber

5 reinforcing material at the weight ratios set forth in Table 7 were melt-mixed as in EXAMPLE 7 to prepare polyamide resin compositions. The physical properties thereof were evaluated, and the results are shown in Table 7.

Table 7

		COMPARATIVE EXAMPLES		
		9	10	11
Polyamide resin A2	Parts by weight	100		
Talc		11	11	11
Mica				
Glass fibers				
Ash content	wt%	10.0	10.0	10.0
Ratio of [ D] ≤ 300 nm	%	0	0	Not measured
Average [ D]	nm	2420	2580	Not measured
Number of dispersed particles [ N]	no./wt% · 100 μm <sup>2</sup>	5	2	Not measured
Average aspect ratio	-	1.5 (*1)	1.5 (*1)	Not measured
Average layer thickness	nm	App. 3,000 (*2)	App. 3,000 (*2)	Not measured
Maximum layer thickness	nm	App. 90,000 (*3)	App. 90,000 (*3)	Not measured
Flexural elastic modulus	MPa	3200	4500	5500
Flexural strength	MPa	108	123	135
Deflection temperature under load	°C	86	97	148
Warpage	mm	7.2	6.5	13.5
Mold shrinkage rate	%			
MD		1.38	1.30	0.44
TD		1.49	1.41	1.56
Centerline average roughness	nm	200	430	700

(\*1): Because dispersed particles were not lamellar, the ratio, major axis/minor axis, of the dispersed particles was determined.

(\*2): Because dispersed particles were not lamellar, the number-average value of the minor axes of the dispersed

particles was determined.

[0175]

(\*3): Because dispersed particles were not lamellar, the maximum value of the minor axis of the dispersed particles  
5 was determined.

Table 7 shows that neither talc nor mica conventionally used exhibited a sufficient reinforcing effect. Moreover, the warpage and the mold shrinkage were not significantly  
10 improved, and the surface quality was degraded. Although the reinforcing effect could be achieved by adding the glass fibers, this adversely affected the warpage and the surface quality. Thus, none of COMPARATIVE EXAMPLES 9 to 11 achieved a satisfactory balance.

15 (EXAMPLE 12 AND COMPARATIVE EXAMPLE 12)

Polyamide resin A3 and the swelling mica prepared in SYNTHETIC EXAMPLE 1 or talc at the weight ratios set forth in Table 8 were melt-mixed using a twin shaft extruder (TEX 44 produced by Japan Steel Works, Ltd.) while adjusting the  
20 temperature to the die to 280°C to 300°C from the initial stage of mixing. The physical properties of the resulting polyamide resin compositions were evaluated, and the results are shown in Table 8.

Table 8

		EXAMPLE 12	COMPARATIVE EXAMPLE 12
Polyamide resin A3	Parts by weight	100	
Clay J-2		13	
Talc			11
Ash content	wt%	9.6	10.0
Ratio of [ D] ≤ 300 nm	%	89	0
Average [ D]	nm	102.5	2420
Number of dispersed particles [ N]	no./wt%	134	5
Average aspect ratio	·100 μm <sup>2</sup>	140	1.5 (* 1)
Average layer thickness	nm	8.5	App. 3,000 (* 2)
Maximum layer thickness	nm	34	App. 90,000 (* 3)
Flexural elastic modulus	MPa	5080	5150
Flexural strength	MPa	145	135
Deflection temperature under load	°C	186	135
Warpage	mm	0.8	1.9
Mold shrinkage rate	%		
MD		0.35	0.54
TD		0.45	0.59
Centerline average roughness	nm	3.8	210

(\* 1): Because dispersed particles were not lamellar, the ratio, major axis/minor axis, of the dispersed particles was determined.

(\* 2): Because dispersed particles were not lamellar, the number-average value of the minor axes of the dispersed particles was determined.

10 (\* 3): Because dispersed particles were not lamellar, the

maximum value of the minor axis of the dispersed particles was determined.

Table 8 shows that the talc conventionally used did not 5 exhibit a sufficient reinforcing effect. Moreover, the warpage and the mold shrinkage were not significantly improved, and the surface quality was degraded.

(EXAMPLE 13 and COMPARATIVE EXAMPLE 13)

Polyamide resin A4 and the swelling mica prepared in 10 SYNTHETIC EXAMPLE 1 or talc at the weight ratios set forth in Table 9 were melt-mixed using a twin shaft extruder (TEX 44 produced by Japan Steel Works, Ltd.) while adjusting the temperature to the dies to 250°C to 290°C from the initial stage of the mixing. The physical properties of the 15 resulting polyamide resin compositions were evaluated, and the results are shown in Table 9.

Table 9

	Parts by weight	EXAMPLE	COMPARATIVE EXAMPLE
		13	13
Polyamide resin A4		100	
Clay J-2		13	
Talc			11
Ash content	wt%	9.5	10.0
Ratio of [ D] ≤ 300 nm	%	102	0
Average [ D]	nm	132	2420
Number of dispersed particles [ N]	no./wt%	120	5
Average aspect ratio	• 100 $\mu\text{m}^2$	125	1.5 (*1)
Average layer thickness	nm	10	App. 3,000 (*2)
Maximum layer thickness	nm	41	App. 90,000 (*3)
Flexural elastic modulus	MPa	7000	4910
Flexural strength	MPa	167	135
Deflection temperature under load	°C	116	88
Warpage	mm	1.0	1.9
Mold shrinkage rate	%		
MD		0.45	1.46
TD		0.54	1.53
Centerline average roughness	nm	4.1	220

(\*1): Because dispersed particles were not lamellar, the ratio, major axis/minor axis, of the dispersed particles was 5 determined.

(\*2): Because dispersed particles were not lamellar, the number-average value of the minor axes of the dispersed particles was determined.

10 (\*3): Because dispersed particles were not lamellar, the

maximum value of the minor axis of the dispersed particles was determined.

Table 9 shows that the talc conventionally used did not exhibit a sufficient reinforcing effect. Moreover, the warpage and the mold shrinkage were not significantly improved, and the surface quality was degraded.

(REFERENCE EXAMPLE 1)

In a reactor can equipped with a stirrer and a reflux condenser, the following substances were charged in a nitrogen gas stream: water (250 parts), sodium formaldehyde sulfoxylate (0.4 part), ferrous sulfate (0.0025 part), disodium ethylenediaminetetraacetate (0.01 part), and sodium dioctylsulfosuccinate (2.0 part). After the mixture was heated to 60°C under stirring, a monomer mixture having a composition set forth in Table 10, cumene hydroperoxide (initiator), and tert-dodecyl mercaptan (polymerization degree adjustor) were continuously added dropwise over 6 hours. The stirring was continued at 60°C for 1 hour after the completion of the dropping. The polymerization was terminated to obtain unsaturated carboxylic acid-containing copolymer (a).

Table 10

		Unsaturated carboxylic acid-containing copolymer (a)
Vinyl monomer (wt%)	$\alpha$ -Methylstyrene	75
	Acrylonitrile	20
	Methacrylic acid	5
Cumene hydroperoxide (parts by weight)		0.3
tert-Dodecyl mercaptan (parts by weight)		0.5

Next, in a reactor can equipped with a stirrer and a reflux condenser, the following substances were charged in a nitrogen gas stream: water (250 parts), potassium persulfate (0.5 part), butadiene (100 parts), tert-dodecyl mercaptan (0.3 part), and disproportionated sodium rosinate (3.0 parts). The polymerization was conducted at 60°C and terminated when the polymerization rate of butadiene reached 80%. Unreacted butadiene was removed to obtain a rubber polymer, i.e., polybutadiene latex (X). The average particle diameter of the polybutadiene rubber was 0.30  $\mu\text{m}$ .

In a reactor can equipped with a stirrer and a reflux condenser, the following substances were charged in a nitrogen gas stream: water (250 parts), sodium formaldehyde sulfoxylate (0.4 part), ferrous sulfate (0.0025 part), disodium ethylenediaminetetraacetate (0.01 part), and polybutadiene (polybutadiene (X) prepared as in the above) in an amount set forth in Table 11. After the mixture was heated to 60°C under stirring, a monomer mixture having a

composition set forth in Table 11, cumene hydroperoxide (initiator), and tert-dodecyl mercaptan (polymerization degree adjustor) were continuously added dropwise over 5 hours. The stirring was continued at 60°C for 1 hour after 5 the completion of the dropping. The polymerization was terminated to obtain graft copolymer (b).

Table 11

		Graft copolymer (b)
Polybutadiene (X)	(wt%)	70
Vinyl monomer (wt%)	Styrene	10
	Methyl methacrylate	20
Cumene hydroperoxide (parts by weight)		0.3
tert-Dodecyl mercaptan (parts by weight)		0.2

The latexes of the unsaturated carboxylic acid-containing copolymer (a) and the graft copolymer (b) obtained as above were homogeneously mixed at a ratio shown in Table 12. A phenolic antioxidant was added to the mixture, and the resulting mixture was coagulated with an aqueous magnesium chloride solution, followed by water washing, dehydration, and drying. An ABS resin was thus obtained.

Table 12

	Styrene resin B1
Unsaturated carboxylic acid-containing copolymer (a) (parts by weight)	64
Graft copolymer (b) (parts by weight)	36

(EXAMPLES 14 to 18 and COMPARATIVE EXAMPLES 14 to 17)

Polyamide resin A1, styrene resins B1 and B2, a  
5 polyphenylene ether resin, the swelling mica prepared in  
SYNTHETIC EXAMPLE 1, and the swelling mica prepared in  
SYNTHETIC EXAMPLE 2 at the weight ratios set forth in Table  
13 were melt-mixed using a twin shaft extruder (TEX 44  
produced by Japan Steel Works, Ltd.) while adjusting the  
10 temperature to the dies to 220°C to 250°C from the initial  
stage of the mixing. The physical properties of the  
resulting polyamide resin compositions were evaluated. The  
results are shown in Table 13.

Table 13 shows that a sufficient reinforcing effect was  
15 not achieved with the swelling mica treated with PVP or an  
ammonium salt. Moreover, the warpage was not substantially  
improved, and deterioration at the processing temperature  
was severe. With the untreated swelling mica, a sufficient  
reinforcing effect was not achieved, the warpage was not  
20 substantially improved, and the surface quality was  
significantly low. The compositions containing a styrene

resin exhibited improved sink mark formation and water absorption compared to those without a styrene resin. The compositions containing a polyphenylene ether resin instead of a styrene resin could not achieve high surface quality.

- 5 The compositions without a polyphenylene ether resin exhibited higher surface quality.

Table 13

\*: Significant deterioration occurred during the melt processing; thus, no specimen usable in measurement was obtained.

5 \*\*: Measurement was not possible due to severe deterioration.

(\*1): Because dispersed particles were not lamellar, the ratio, major axis/minor axis, of the dispersed particles was determined.

(\*2): Because dispersed particles were not lamellar, the 10 number-average value of the minor axes of the dispersed particles was determined.

(\*3): Because dispersed particles were not lamellar, the maximum value of the minor axis of the dispersed particles was determined.

15 (COMPARATIVE EXAMPLES 19 to 21)

Polyamide resin A1, styrene resin B1, talc, mica, and a glass fiber reinforcing material at the weight ratios set forth in Table 14 were melt-mixed as in EXAMPLE 14 to prepare polyamide resin compositions. The properties 20 thereof were evaluated. The results are shown in Table 14.

Table 14

		COMPARATIVE EXAMPLES		
		19	20	21
Polyamide resin A1	Parts by weight	55	55	55
Styrene resin B1		45	45	45
Talc		6.5		
Mica			6.5	
Glass fibers				6.5
Ash content	wt%	6.1	6.1	6.1
Ratio of [ D] ≤ 300 nm	%	0	0	Not measured
Average [ D]	nm	2420	5200	Not measured
Number of dispersed particles [ N]	no./wt% · 100 μm <sup>2</sup>	5	1	Not measured
Average aspect ratio	-	1.5 (*1)	2.0 (*1)	Not measured
Average layer thickness	nm	App. 3,000 (*2)	App. 5,000 (*2)	Not measured
Maximum layer thickness	nm	App. 90,000 (*3)	App. 120,000 (*3)	Not measured
Flexural elastic modulus	MPa	2650	2800	3800
Flexural strength	MPa	95	102	115
Deflection temperature under load	°C	132	128	155
Warpage	mm	3.8	4.3	7.5
Centerline average roughness	nm	230	410	650
Sink mark formation	mm	2	2	2
Water absorption	%	0.8	0.9	0.8

(\*1): Because dispersed particles were not lamellar, the ratio, major axis/minor axis, of the dispersed particles was 5 determined.

(\*2): Because dispersed particles were not lamellar, the number-average value of the minor axes of the dispersed particles was determined.

(\*3): Because dispersed particles were not lamellar, the maximum value of the minor axis of the dispersed particles was determined.

5       Table 14 shows that neither talc nor mica conventionally used exhibited a sufficient reinforcing effect or substantially improved heat resistance or warpage, thus resulting in low surface quality. Although the reinforcing effect and the heat resistance could be achieved  
10 by adding the glass fibers, this adversely affected the warpage and surface quality. Thus, none of COMPARATIVE EXAMPLES 19 to 21 achieved a satisfactory balance.

(EXAMPLES 19 to 22)

Polyamide resin A1, styrene resin B1, and the swelling  
15 mica obtained in SYNTHETIC EXAMPLE 1 at the weight ratios set forth in Table 15 were melt-mixed using a twin shaft extruder (TEX 44 produced by Japan Steel Works, Ltd.) while adjusting the temperature to the dies to 220°C to 250°C from the initial stage of the mixing. The physical properties of  
20 the resulting polyamide resin compositions were evaluated. The results are shown in Table 15.

Table 15

		EXAMPLES			
		19	20	21	22
Polyamide resin A1	Parts by weight	55	55	55	70
Styrene resin B1		45	45	45	30
Clay J-2		5	12	17	12
Ash content	wt%	4.0	8.9	12.1	8.9
Ratio of [ D ] ≤ 300 nm	%	92	85	77	89
Average [ D ]	nm	100	121	142	101
Number of dispersed particles [ N ]	no./wt% · 100 μm <sup>2</sup>	140	129	114	138
Average aspect ratio	-	138	140	112	142
Average layer thickness	nm	8.3	8.8	11.2	8.1
Maximum layer thickness	nm	34	33	48	33
Flexural elastic modulus	MPa	3200	4200	4800	4600
Flexural strength	MPa	102	119	123	120
Deflection temperature under load	°C	155	165	171	175
Warpage	mm	0.9	0.5	0.5	1.0
Centerline average roughness	nm	2.5	3.2	4.3	2.0
Sink mark formation	mm	1.6	1.6	1.8	1.6
Water absorption	%	0.8	0.8	0.7	1.2

(EXAMPLES 23 to 26)

Polyamide resin A2, styrene resin B1, and the swelling 5 mica obtained in SYNTHETIC EXAMPLE 1 at the weight ratios set forth in Table 16 were melt-mixed using a twin shaft extruder (TEX 44 produced by Japan Steel Works, Ltd.) while adjusting the temperature to the dies to 230°C to 260°C from the initial stage of the mixing. The physical properties of

the resulting polyamide resin compositions were evaluated.

The results are shown in Table 16.

Table 16

	Parts by weight	EXAMPLES			
		23	24	25	26
Polyamide resin A2	60	60	60	60	
Polystyrene resin B1	40	40	40	40	
Clay J-1	10				
Clay J-2		8			
Clay J-3			7		
Clay J-4					9
Ash content	wt%	6.1	6.2	5.9	6.3
Ratio of [ D ] ≤ 300 nm	%	90	81	72	40
Average [ D ]	nm	110	143	193	388
Number of dispersed particles [ N ]	no./wt% · 100 μm <sup>2</sup>	141	100	80	49
Average aspect ratio	-	140	109	101	53
Average layer thickness	nm	8.2	10.5	13.9	31
Maximum layer thickness	nm	31	45	61	139
Flexural elastic modulus	MPa	4000	4000	3900	3800
Flexural strength	MPa	113	112	110	103
Deflection temperature under load	°C	188	183	179	172
Warpage	mm	0.7	0.9	1.0	1.5
Centerline average roughness	nm	3.5	4.0	4.0	6.0
Sink mark formation	mm	1.8	1.8	1.8	1.6
Water absorption	%	0.5	0.5	0.5	0.5

5 (COMPARATIVE EXAMPLES 22 to 24)

Polyamide resin A2, styrene resin B1, talc, mica, and a glass fiber reinforcing material at the weight ratios set

forth in Table 17 were melt-mixed as in EXAMPLE 23. The physical properties of the resulting polyamide resin compositions were evaluated. The results are shown in Table 17.

5 Table 17

	Parts by weight	COMPARATIVE EXAMPLES		
		22	23	24
Polyamide resin A2	60	60	60	
Styrene resin B1	40	40	40	
Talc	6.5			
Mica		6.5		
Glass fibers			6.5	
Ash content	wt%	6.1	6.1	6.1
Ratio of [ D] ≤ 300 nm	%	0	0	Not measured
Average [ D]	nm	2450	5300	Not measured
Number of dispersed particles [ N]	no./wt% · 100 μm <sup>2</sup>	5	2	Not measured
Average aspect ratio	-	1.5 (* 1)	2.0 (* 1)	Not measured
Average layer thickness	nm	App. 3,000 (* 2)	App. 5,000 (* 2)	Not measured
Maximum layer thickness	nm	App. 90,000 (* 3)	App. 110,000 (* 3)	Not measured
Flexural elastic modulus	MPa	2700	3100	4000
Flexural strength	MPa	97	123	135
Deflection temperature under load	°C	148	147	167
Warpage	mm	3.9	4.2	8
Centerline average roughness	nm	210	430	710
Sink mark formation	mm	1.60	1.60	1.60
Water absorption	%	0.5	0.5	0.5

(\* 1): Because dispersed particles were not lamellar, the

ratio, major axis/minor axis, of the dispersed particles was determined.

(\*2): Because dispersed particles were not lamellar, the number-average value of the minor axes of the dispersed  
5 particles was determined.

(\*3): Because dispersed particles were not lamellar, the maximum value of the minor axis of the dispersed particles was determined.

10 Table 17 shows that neither talc nor mica conventionally used exhibited a sufficient reinforcing effect or sufficiently improved the heat resistance and the warpage, thus severely degrading the surface quality.

15 Although the reinforcing effect could be achieved by adding glass fibers, the warpage was not sufficiently improved and the surface quality was severely degraded. Thus, none of COMPARATIVE EXAMPLES 22 to 24 achieved a satisfactory balance.

20 (EXAMPLE 27 and COMPARATIVE EXAMPLE 25)

Polyamide resin A4, styrene resin B1, and the swelling mica obtained in SYNTHETIC EXAMPLE 1 or talc at the weight ratios set forth in Table 18 were melt-mixed using a twin shaft extruder (TEX 44 produced by Japan Steel Works, Ltd.)  
25 while adjusting the temperature to the dies to 280°C to

300°C from the initial stage of the mixing. The physical properties of the resulting polyamide resin compositions were evaluated. The results are shown in Table 18.

Table 18

	Parts by weight	EXAMPLE	COMPARATIVE EXAMPLE
		27	25
Polyamide resin A4		55	55
Styrene resin B1		45	45
Clay J-2		8	
Talc			6.5
Ash content	wt%	6.2	6.1
Ratio of [ D ] ≤ 300 nm	%	102	0
Average [ D ] nm	nm	132	2400
Number of dispersed particles [ N ]	no./wt% · 100 μm <sup>2</sup>	120	5
Average aspect ratio	-	125	1.5 (*1)
Average layer thickness	nm	10	App. 3,000 (*2)
Maximum layer thickness	nm	41	App. 90,000 (*3)
Flexural elastic modulus	MPa	5700	3900
Flexural strength	MPa	153	129
Deflection temperature under load	°C	171	139
Warpage	mm	0.6	4.5
Centerline average roughness	nm	6	250
Sink mark formation	mm	1.60	1.40
Water absorption	%	0.3	0.3

5

(\*1): Because dispersed particles were not lamellar, the ratio, major axis/minor axis, of the dispersed particles was determined.

(\*2): Because dispersed particles were not lamellar, the

number-average value of the minor axes of the dispersed particles was determined.

(\*3): Because dispersed particles were not lamellar, the maximum value of the minor axis of the dispersed particles  
5 was determined.

Table 18 shows that the talc conventionally used did not exhibit a sufficient reinforcing effect or a sufficient warpage improvement. Thus, the surface quality was low.

10

(EXAMPLES 28 to 31 and COMPARATIVE EXAMPLES 26 to 29)

Polyamide resin A1, anhydride-containing olefin copolymer C2, an ethylene-propylene-diene copolymer (EP96 produced by JSR Corporation), the swelling mica obtained in  
15 SYNTHETIC EXAMPLE 1, the swelling mica obtained in SYNTHETIC EXAMPLE 2, glass fibers, and mica at the weight ratios set forth in Table 19 were melt-mixed using a twin shaft extruder (TEX 44 produced by Japan Steel Works, Ltd.) while adjusting the temperature to 240°C. The physical properties  
20 of the resulting polyamide resin compositions were evaluated. The results are shown in Table 19.

Table 19

		EXAMPLES					COMPARATIVE EXAMPLES		
		28	29	30	31	26	27	28	29
Polyamide resin A1 Anhydride-containing olefin copolymer C2 Ethylene-propylene-diene copolymer Clay J-2 Clay J-5 Clay K-2 Clay K-4 Glass Fibers Mica	Parts by weight	85 5	83.6 5	85	83.6 5	81 5	81 5	85 5	85 5
		10	11.4	10	11.4	14	14	10	10
	%	92	85	90	86	Not measured	Not measured	Not measured	0
	nm	99	112	99	110	Not measured	Not measured	Not measured	2420
	no./m²%·100 μm²	139	112	137	120	Not measured	Not measured	Not measured	3
	-	145	105	145	107	Not measured	Not measured	Not measured	1.5 (*1)
Average aspect ratio		8	9.5	8	9.5	Not measured	Not measured	Not measured	App. 2000 (*2)
Average layer thickness	nm	30	41	29	40	Not measured	Not measured	Not measured	App. 70,000 (*3)
Maximum layer thickness	nm					Measured	Measured	Measured	
Stiffness (flexural elastic modulus)	MPa	4450	4210	4400	4150	3480	3620	4780	3360
Warpage upon water absorption	mm	1.5	1.6	5.9	7.8	3.1	3.4	24.3	5.7
Surface quality (surface roughness)	nm	4.4	6.8	5.0	6.0	10.2	9.5	650	230
Melt heat stability (Flow)	After 5 min After 15 min	×10 <sup>-2</sup> ml/sec ×10 <sup>-2</sup> ml/sec	27.3 27.9	28.6 29.0	28.7 29.1	30.1 30.4	45.6 89.5	38.9 68.3	34.5 35.2
Color after 15 min			None	None	None	Yellow	Yellow	None	None

(\*1): Because dispersed particles were not lamellar, the ratio, major axis/minor axis, of the dispersed particles was determined.

5 (\*2): Because dispersed particles were not lamellar, the number-average value of the minor axes of the dispersed particles was determined.

(\*3): Because dispersed particles were not lamellar, the maximum value of the minor axis of the dispersed particles was determined.

10

(EXAMPLES 32 to 37)

Polyamide resin A1, anhydride-containing olefin copolymer C2, and the swelling mica obtained in SYNTHETIC EXAMPLES 1 at the weight ratios set forth in Table 20 were 15 melt-mixed using a twin shaft extruder (TEX 44 produced by Japan Steel Works, Ltd.). The physical properties of the resulting polyamide resin compositions were evaluated. The results are shown in Table 20.

Table 20

		EXAMPLES					
		32	33	34	35	36	37
Polyamide resin A1 Anhydride-containing olefin copolymer C2 Clay J-2	Parts by weight	89	80	60	94.2	80	65
		1	10	30	5	5	5
		10	10	10	0.8	15	30
Ratio of [D] ≤ 300 nm	%	93	89	85	95	88	76
Average [D]	nm	98	98	103	84	118	136
Number of dispersed particles [N]	no./wt%·100 μm <sup>2</sup>	142	136	128	160	126	105
Average aspect ratio	-	150	140	129	176	117	89
Average layer thickness	nm	7.5	8.8	9.5	6	12.5	15
Maximum layer thickness	nm	28	35	41	18	42	65
Stiffness (flexural elastic modulus)	MPa	5370	4010	2860	2950	5120	6780
Warpage upon water absorption	mm	1.8	1.4	1	3.6	1.2	0.8
Surface quality (surface roughness)	nm	3.0	3.5	4.9	0.6	4.8	6.0
Melt heat stability (Flow)	After 5 min After 15 min	×10 <sup>-2</sup> ml/sec ×10 <sup>-2</sup> ml/sec	29.1 29.3	25.2 25.9	19.4 22.1	36.2 36.3	24.3 25.8
Color after 15 min			None	None	None	None	None

(EXAMPLES 38 to 41)

Polyamide resin A1, anhydride-containing olefin  
 5 copolymers C1 and C3, and the swelling mica obtained in  
 SYNTHETIC EXAMPLES 1 at the weight ratios set forth in Table  
 21 were melt-mixed using a twin shaft extruder (TEX 44  
 produced by Japan Steel Works, Ltd.) at 240°C. The physical  
 properties of the resulting polyamide resin compositions  
 10 were evaluated. The results are shown in Table 21.

Table 21

		EXAMPLES			
		38	39	40	41
Polyamide resin A1	Parts by weight	86	83	86	83
Anhydride-containing olefin copolymer C1		5	5		
Anhydride-containing olefin copolymer C3				5	5
Clay J-3 Clay J-6		9	12	9	12
Ratio of [D] ≤ 300 nm	%	85	80	84	79
Average [D]	nm	116	120	118	119
Number of dispersed particles [N]	no./wt%·100 μm <sup>2</sup>	118	105	120	110
Average aspect ratio	-	120	106	117	108
Average layer thickness	nm	9.6	11.5	10	11.8
Maximum layer thickness	nm	47	52	45	55
Stiffness (flexural elastic modulus)	MPa	4210	3890	4160	3820
Warpage upon water absorption	mm	1.8	2.2	1.9	2.3
Surface quality (surface roughness)	nm	4.5	5.7	4.9	5.7
Melt heat stability	After 5 min	×10 <sup>-2</sup> ml/sec	32.1	30.6	34.6
(Flow)	After 15 min	×10 <sup>-2</sup> ml/sec	33.4	31.2	35.7
Color after 15 min			None	None	None

(EXAMPLES 42 to 43)

Polyamide resin A2, anhydride-containing olefin

5 copolymer C2, and the swelling mica obtained in SYNTHETIC EXAMPLES 1 at the weight ratios set forth in Table 22 were melt-mixed using a twin shaft extruder (TEX 44 produced by Japan Steel Works, Ltd.) at 260°C. The physical properties of the resulting polyamide resin compositions were evaluated.

10 The results are shown in Table 22.

Table 22

		EXAMPLES		
		42	43	
Polyamide resin A2	Parts by weight	85	83.6	
Anhydride-containing olefin copolymer C2		5	5	
Clay J-2 Clay J-5		10	11.4	
Ratio of [D] ≤ 300 nm	%	93	88	
Average [D]	nm	98	105	
Number of dispersed particles [N]	no./wt%·100 μm <sup>2</sup>	140	122	
Average aspect ratio	-	145	107	
Average layer thickness	nm	8.5	9.5	
Maximum layer thickness	nm	32	40	
Stiffness (flexural elastic modulus)	MPa	4620	4330	
Warpage upon water absorption	mm	1.2	1.4	
Surface quality (surface roughness)	nm	4.3	5.5	
Melt heat stability (Flow)	After 5 min After 15 min	×10 <sup>-2</sup> ml/sec ×10 <sup>-2</sup> ml/sec	28.1 28.7	29.4 29.6
Color after 15 min		None	None	

The results above show that, with the swelling mica

treated with the ammonium salt, the melt heat stability was

5 low, and the flow of the resin was unstable, resulting in color development. With the glass fibers and the mica, the surface quality was impaired and warpage occurred. With the olefin copolymer containing no anhydride, the warpage property upon absorption of water was not sufficient. Thus, 10 polyamide resin compositions of EXAMPLES exhibited a satisfactory balance between properties while none of COMPARATIVE EXAMPLES achieved a satisfactory balance.

(EXAMPLES 44 to 49)

Polyamide resin A1, the swelling mica obtained in

15 SYNTHETIC EXAMPLES 1, and carbon compounds G1 and G2 at the

weight ratios set forth in Table 23 were melt-mixed using a twin shaft extruder (TEX 44 produced by Japan Steel Works, Ltd.) while adjusting the temperature to the dies to 220°C to 250°C from the initial stage of the mixing. The physical properties of the resulting polyamide resin compositions were evaluated. The results are shown in Table 23.

Table 23

		EXAMPLES			
Polyamide resin A1	Parts by weight	44	45	46	47
		100	100	100	91
Clay J-2		6.6	6.6	13.6	6.6
				18	13.6
Clay J-6		3.5	4.5	4.5	9
				4.5	9
Carbon compound G1					9
					9
Carbon compound G2					9
					9
Ash content	wt%	5.0	5.0	9.9	10.2
Ratio of $[D] \leq 300$ nm	%	93	92	90	81
Average $[D]$	nm	98	99	104	117
Number of dispersed particles [N]	no./wt%·100 $\mu\text{m}^2$	146	144	135	113
Average aspect ratio	-	125	125	140	108
Average layer thickness	nm	8	8	8.5	9.5
Maximum layer thickness	nm	30	31	33	39
Flexural elastic modulus	MPa	4200	4150	5450	5100
Flexural strength	MPa	105	104	130	130
Deflection temperature under load	°C	130	131	145	139
Volume resistivity	$\Omega \cdot \text{cm}$	$1.9 \times 10^{11}$	$3.2 \times 10^5$	$9.4 \times 10^4$	$7.5 \times 10^5$
Warpage	mm	1.6	1.5	1.3	1.6
Mold shrinkage rate	%	0.67	0.65	0.44	0.47
	MD	0.69	0.68	0.49	0.53
	TD				
Centerline average roughness	nm	2.5	2.6	4.0	4.0
				2.0	2.0
				3.4	3.4

(\*1): Because dispersed particles were not lamellar, the ratio, major axis/minor axis, of the dispersed particles was determined.

5 (\*2): Because dispersed particles were not lamellar, the number-average value of the minor axes of the dispersed particles was determined.

(\*3): Because dispersed particles were not lamellar, the maximum value of the minor axis of the dispersed particles was determined.

10

(COMPARATIVE EXAMPLES 30 to 34)

Polyamide resin A1, talc, mica, glass fibers, and carbon compound G1 at the weight ratios set forth in Table 24 were melt-mixed as in EXAMPLE 44. The physical 15 properties of the resulting polyamide resin compositions were evaluated. The results are shown in Table 24.

Table 24

		COMPARATIVE EXAMPLES				
		30	31	32	33	34
Polyamide resin A1	Parts by weight	100	100	100	100	100
Talc				11		
Mica					11	
Glass fibers						11
Carbon compound G1			4.5	4.5	4.5	4.5
Ash content	wt%	0.0	0.0	10.0	9.9	9.9
Ratio of [D] ≤ 300 nm	%	Not measured	Not measured	0	0	Not measured
Average [D]	nm	Not measured	Not measured	2420	2580	Not measured
Number of dispersed particles [N]	no./wt% ·100 μm <sup>2</sup>	Not measured	Not measured	5	2	Not measured
Average aspect ratio	-	Not measured	Not measured	1.5 (*1)	1.5 (*1)	Not measured
Average layer thickness	nm	Not measured	Not measured	App. 3,000 (*2)	App. 3,000 (*2)	Not measured
Maximum layer thickness	nm	Not measured	Not measured	App. 90,000 (*3)	App. 90,000 (*3)	Not measured
Flexural elastic modulus	MPa	2700	2730	3010	4250	5400
Flexural strength	MPa	96	96	95	120	130
Deflection temperature under load	°C	69	70	72	90	148
Volume resistivity	Ω·cm	7.0 × 10 <sup>14</sup>	9.5 × 10 <sup>5</sup>	7.1 × 10 <sup>5</sup>	4.4 × 10 <sup>5</sup>	2.1 × 10 <sup>5</sup>
Warpage	mm	8.1	8.0	7.8	7.1	16.2
Mold shrinkage rate	%					
MD		1.59	1.60	1.43	1.01	0.56
TD		1.70	1.72	1.59	1.21	1.78
Centerline average roughness	nm	1.9	2.2	210	430	890

(\* 1) : Because dispersed particles were not lamellar, the ratio, major axis/minor axis, of the dispersed particles was determined.

5

(\* 2) : Because dispersed particles were not lamellar, the number-average value of the minor axes of the dispersed particles was determined.

(\*3): Because dispersed particles were not lamellar, the maximum value of the minor axis of the dispersed particles was determined.

5 (EXAMPLES 50 to 52)

Polyamide resin A2, the swelling mica obtained in SYNTHETIC EXAMPLE 1, and carbon compounds G1 and G3 at the weight ratios set forth in Table 25 were melt-mixed using a twin shaft extruder (TEX 44 produced by Japan Steel Works, Ltd.) while adjusting the temperature to the dies to 230°C to 260°C from the initial stage of the mixing. The properties of the resulting compositions were evaluated, and the results are shown in Table 25.

Table 25

		EXAMPLES		
		50	51	52
Polyamide resin A2	Parts by weight	100	100	91
Clay J-2		13.6		13.6
Clay J-6			18	
Carbon compound G1		4.5	4.5	
Carbon compound G3				9
Ash content	wt%	9.9	9.8	10.1
Ratio of [D] ≤ 300 nm	%	81	36	80
Average [D]	nm	142	283	141
Number of dispersed particles [N]	no./wt%	99	45	103
Average aspect ratio	·100	106	50	106
Average layer thickness	μm <sup>2</sup>	10.5	36	10.5
Maximum layer thickness	-	51	165	50
Flexural elastic modulus	MPa	5580	4950	5410
Flexural strength	MPa	116	96	119
Deflection temperature under load	°C	141	131	143
Volume resistivity	Ω · cm	3.7 × 10 <sup>5</sup>	5.9 × 10 <sup>5</sup>	1.7 × 10 <sup>8</sup>
Warpage	mm	1.0	3.6	1.4
Mold shrinkage rate	%			
MD		0.30	0.68	0.44
TD		0.32	0.72	0.50
Centerline average roughness	nm	4.5	7.3	3.5

(COMPARATIVE EXAMPLES 35 to 39)

Polyamide resin A2, talc, mica, glass fibers, and  
 5 carbon compound G1 at the weight ratios set forth in Table  
 26 were melt-mixed as in EXAMPLE 50. The physical  
 properties of the resulting polyamide resin compositions  
 were evaluated. The results are shown in Table 26.

Table 26

		COMPARATIVE EXAMPLES				
		35	36	37	38	39
Polyamide resin A2	Parts by weight	100	100	100	100	100
Talc				11		
Mica					11	
Glass fibers						11
Carbon compound G1			4.5	4.5	4.5	4.5
Ash content	wt%	0.0	0.0	10.0	10.0	10.0
Ratio of [D] ≤ 300 nm	%	Not measured	Not measured	0	0	Not measured
Average [D]	nm	Not measured	Not measured	2420	2580	Not measured
Number of dispersed particles [N]	no./wt% ·100 μm <sup>2</sup>	Not measured	Not measured	5	2	Not measured
Average aspect ratio	-	Not measured	Not measured	1.5 (*1)	1.5 (*1)	Not measured
Average layer thickness	nm	Not measured	Not measured	App. 3,000 (*2)	App. 3,000 (*2)	Not measured
Maximum layer thickness	nm	Not measured	Not measured	App. 90,000 (*3)	App. 90,000 (*3)	Not measured
Flexural elastic modulus	MPa	2900	2910	3200	4500	5500
Flexural strength	MPa	113	112	108	123	135
Deflection temperature under load	°C	80	81	86	97	148
Volume resistivity	Ω·cm	6.4 × 10 <sup>14</sup>	8.9 × 10 <sup>5</sup>	7.4 × 10 <sup>5</sup>	3.9 × 10 <sup>5</sup>	2.2 × 10 <sup>5</sup>
Warpage	mm	8.3	7.9	7.2	6.5	13.5
Mold shrinkage rate	%					
MD		1.47	1.46	1.38	1.30	0.44
TD		1.56	1.54	1.49	1.41	1.56
Centerline average roughness	nm	2.0	2.2	200	430	700

(\* 1) : Because dispersed particles were not lamellar, the ratio, major axis/minor axis, of the dispersed particles was determined.

(\* 2) : Because dispersed particles were not lamellar, the number-average value of the minor axes of the dispersed particles was determined.

(\*3): Because dispersed particles were not lamellar, the maximum value of the minor axis of the dispersed particles was determined.

5 (EXAMPLES 53 to 55)

Polyamide resin A3, the swelling mica obtained in SYNTHETIC EXAMPLE 1, and carbon compounds G1 and G3 at the weight ratios set forth in Table 27 were melt-mixed using a twin shaft extruder (TEX 44 produced by Japan Steel Works, Ltd.) while adjusting the temperature to the dies to 280°C to 300°C from the initial stage of the mixing. The properties of the resulting polyamide resin compositions were evaluated, and the results are shown in Table 27.

Table 27

		EXAMPLES		
		53	54	55
Polyamide resin A3	Parts by weight	100	100	91
Clay J-2		13.6		13.6
Clay J-6			18	
Carbon compound G1		4.5	4.5	
Carbon compound G3				9
Ash content	wt%	9.8	9.8	10.1
Ratio of [D] ≤ 300 nm	%	88	37	89
Average [D]	nm	103	280	99
Number of dispersed particles [N]	no./wt%	130	50	136
	·100 $\mu\text{m}^2$			
Average aspect ratio	-	142	52	145
Average layer thickness	nm	9	35	9.5
Maximum layer thickness	nm	35	165	36
Flexural elastic modulus	MPa	5090	4850	5180
Flexural strength	MPa	148	96	150
Deflection temperature under load	°C	188	123	190
Volume resistivity	$\Omega \cdot \text{cm}$	$2.9 \times 10^5$	$6.1 \times 10^5$	$1.8 \times 10^8$
Warpage	mm	0.8	3.8	1.3
Mold shrinkage rate	%			
MD		0.35	0.68	0.34
TD		0.45	0.72	0.48
Centerline average roughness	nm	4.0	7.3	3.5

(COMPARATIVE EXAMPLES 40 to 44)

Polyamide resin A3, talc, mica, glass fibers, and  
 5 carbon compound G1 at the weight ratios set forth in Table  
 28 were melt-mixed as in EXAMPLE 53. The physical  
 properties of the resulting polyamide resin compositions  
 were evaluated. The results are shown in Table 28.

Table 28

		COMPARATIVE EXAMPLES				
		40	41	42	43	44
Polyamide resin A3	Parts by weight	100	100	100	100	100
Talc				11		
Mica					11	
Glass fibers						11
Carbon compound G1			4.5	4.5	4.5	4.5
Ash content	wt%	0.0	0.0	10.0	10.0	10.0
Ratio of [D] ≤ 300 nm	%	Not measured	Not measured	0	0	Not measured
Average [D]	nm	Not measured	Not measured	2420	2580	Not measured
Number of dispersed particles [N]	no./wt% ·100 μm <sup>2</sup>	Not measured	Not measured	5	2	Not measured
Average aspect ratio	-	Not measured	Not measured	1.5 (*1)	1.5 (*1)	Not measured
Average layer thickness	nm	Not measured	Not measured	App. 3,000 (*2)	App. 3,000 (*2)	Not measured
Maximum layer thickness	nm	Not measured	Not measured	App. 90,000 (*3)	App. 90,000 (*3)	Not measured
Flexural elastic modulus	MPa	3200	3200	5150	5400	5810
Flexural strength	MPa	150	150	135	137	140
Deflection temperature under load	°C	130	130	135	139	148
Volume resistivity	Ω·cm	3.3 × 10 <sup>14</sup>	9.8 × 10 <sup>5</sup>	8.3 × 10 <sup>5</sup>	3.9 × 10 <sup>5</sup>	2.4 × 10 <sup>5</sup>
Warpage	mm	4.5	4.5	1.9	2.5	14.7
Mold shrinkage rate	%					
MD		1.01	1.01	0.54	0.45	0.32
TD		1.11	1.11	0.59	0.49	1.43
Centerline average roughness	nm	1.9	1.9	210	430	790

(\* 1) : Because dispersed particles were not lamellar, the ratio, major axis/minor axis, of the dispersed particles was determined.

(\* 2) : Because dispersed particles were not lamellar, the number-average value of the minor axes of the dispersed particles was determined.

(\* 3): Because dispersed particles were not lamellar, the maximum value of the minor axis of the dispersed particles was determined.

5 (EXAMPLES 56 to 58)

Polyamide resin A4, the swelling mica obtained in SYNTHETIC EXAMPLE 1, and carbon compounds G1 and G3 at the weight ratios set forth in Table 29 were melt-mixed using a twin shaft extruder (TEX 44 produced by Japan Steel Works, Ltd.) while adjusting the temperature to the dies to 280°C to 300°C from the initial stage of the mixing. The properties of the resulting polyamide resin compositions were evaluated, and the results are shown in Table 29.

Table 29

		EXAMPLES		
		56	57	58
Polyamide resin A4	Parts by weight	100	100	91
Clay J-2		13.6		13.6
Clay J-6			18	
Carbon compound G1		4.5	4.5	
Carbon compound G3				9
Ash content	wt%	9.5	9.6	10.1
Ratio of [D] ≤ 300 nm	%	103	45	97
Average [D]	nm	133	226	129
Number of dispersed particles [N]	no./wt%	123	58	130
Average aspect ratio	·100			
Average layer thickness	μm <sup>2</sup>	120	59	133
Maximum layer thickness	-	10.5	33	9.5
Flexural elastic modulus	nm	40.5	138	35.5
Flexural strength	MPa	7200	5010	7290
Deflection temperature under load	MPa	168	113	170
Volume resistivity	°C	118	109	123
Warpage	Ω·cm	4.8 × 10 <sup>5</sup>	6.1 × 10 <sup>5</sup>	2.8 × 10 <sup>8</sup>
Mold shrinkage rate	mm	1.0	3.9	1.2
MD	%	0.45	0.68	0.34
TD		0.54	0.73	0.45
Centerline average roughness	nm	4.2	6.4	3.0

(COMPARATIVE EXAMPLES 45 to 49)

Polyamide resin A4, talc, mica, glass fibers, and carbon compound G1 at the weight ratios set forth in Table 30 were melt-mixed using a twin shaft extruder (TEX 44 produced by Japan Steel Works, Ltd.) as in EXAMPLE 56. The physical properties of the resulting polyamide resin compositions were evaluated. The results are shown in Table 30.

Table 30

		COMPARATIVE EXAMPLES				
		45	46	47	48	49
Polyamide resin A4	Parts by weight	100	100	100	100	100
Talc				11		
Mica					11	
Glass fibers						11
Carbon compound G1			4.5	4.5	4.5	4.5
Ash content	wt%	0.0	0.0	10.0	10.0	10.0
Ratio of [D] ≤ 300 nm	%	Not measured	Not measured	0	0	Not measured
Average [D]	nm	Not measured	Not measured	2450	2500	Not measured
Number of dispersed particles [N]	no./wt% ·100 μm <sup>2</sup>	Not measured	Not measured	5	2	Not measured
Average aspect ratio	-	Not measured	Not measured	1.5 (*1)	1.5 (*1)	Not measured
Average layer thickness	nm	Not measured	Not measured	App. 3,000 (*2)	App. 3,000 (*2)	Not measured
Maximum layer thickness	nm	Not measured	Not measured	App. 90,000 (*3)	App. 90,000 (*3)	Not measured
Flexural elastic modulus	MPa	4500	4600	4910	5500	5900
Flexural strength	MPa	159	161	135	140	149
Deflection temperature under load	°C	84	85	88	100	121
Volume resistivity	Ω·cm	9.4 × 10 <sup>14</sup>	1.0 × 10 <sup>5</sup>	7.4 × 10 <sup>5</sup>	4.9 × 10 <sup>5</sup>	2.5 × 10 <sup>5</sup>
Warpage	mm	6.9	6.7	3.0	3.6	16.2
Mold shrinkage rate	%					
	MD	1.45	1.43	1.48	1.00	0.29
	TD	1.53	1.54	1.55	1.09	1.45
Centerline average roughness	nm	1.9	2.0	240	440	890

(\* 1) : Because dispersed particles were not lamellar, the ratio, major axis/minor axis, of the dispersed particles was determined.

(\* 2) : Because dispersed particles were not lamellar, the number-average value of the minor axes of the dispersed particles was determined.

(\* 3): Because dispersed particles were not lamellar, the maximum value of the minor axis of the dispersed particles was determined.

5 EXAMPLES and COMPARATIVE EXAMPLES demonstrate that addition of carbon compounds to polyamide resins decreases the resistivity, but the balance between heat resistance and dimensional stability is not satisfactory. Addition of glass fibers can render heat resistance but causes  
10 anisotropic shrinkage, which leads to warpage, low dimensional stability, and low surface quality. The combination of talc and mica can render electric conductivity and dimensional stability but degrades surface quality. Accordingly, it is clear that none of the  
15 conventional techniques can provide a conductive material that can achieve satisfactory balance between electric conductivity, mechanical strength, heat resistance, surface quality of the product, mold shrinkage, and dimensional stability such as anisotropy and warpage.

20

#### Industrial Applicability

As is described above, the swelling mica treated with the polyether compound according to the present invention achieves homogeneous, fine dispersion in the polyamide resin.

25 Thus, a polyamide resin composition exhibiting low warpage,

satisfactory dimensional stability, good surface appearance, improved mechanical properties, and high heat resistance can be obtained while achieving a satisfactory balance between these properties.

5        Moreover, addition of a styrene resin provides a polyamide resin composition that can exhibit superior surface appearance (surface quality and low sink mark formation) in addition to the above-described effects; addition of an anhydride-containing olefin copolymer

10      provides a polyamide resin composition exhibiting low water absorption in addition to the above-described effects; and addition of a carbon compound can provide a polyamide resin composition having antistatic properties in addition to the above-described effects.